SOME ASPECTS OF ECOPHYSIOLOGY AND BIOLOGICAL CONCERNS OF THE ESTUARINE MULLET *LIZA MACROLEPIS* (SMITH) WITH REFERENCE TO HEAVY METALS POLLUTION

THESIS

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1.0.0 INTRODUCTION

In recent years, there is a global awareness for increased fish production under natural and culture conditions of coastal embayments (FAO, 1976, 1977) which constitute one of the most valuable and vulnerable natural resources of a nation's economy (Gunter, 1938; Lobel, 1939; Warfel and Merriman, 1944; Reid, 1954; June and Reintjes, 1957; Arnold, *et al*., 1960; Fisk *et al*., 1966; Jerome *et al*., 1966; Ketchum, 1967; Gunter, 1967; Odum, 1969, 1970; Espey and Ward, 1972; Pillai, 1972, 1973; Kurian, 1973; Shepherd, 1974; Ganapati, 1975; Qasim, 1975; Silas *et al*., 1976; Rao and Madhupratap, 1981). Currently, in India, there is a growing interest in aquaculture from the above standpoint. Hence, information on the relative abundance of cultivable fish seed together with physico-chemical conditions of the environment is a very essential prerequisite. In aquaculture practices, the seed for planting are generally collected from the natural ecosystem and then transported to culture areas (Ramanathan and Jayamaha, 1972 and Pillai, 1972). Such a practice has to be done in the absence of any standard technology for the mass production of fish seed by induced breeding. Therefore, collection of seed from the natural environment is the only major source. From this standpoint, Jhingran (1969) and Pillai (1972) stressed the need for undertaking further survey of cultivable seed resources and for locating potential areas of seed abundance. Further, with the increased emphasis given by the Government of India to aquaculture, there is a growing demand for seed requirement by the fish farmers and private entrepreneurs.

There are about eight estuaries along the Madras coast. They are: Pulicat, Ennore, Adyar, Cooum, Kovalam, Edayur, Sadras and Palar. Many workers have surveyed the abundance of fish seed resources from the coastal estuaries of Madras (Chacko and Ganapathi, 1949; Chacko, 1952, 1956; Abraham, 1962; Evangeline, 1968; Evangeline, et al., 1969; Evangeline and Subbiah, 1969; Prabhakara Rao, 1970; Krishnan and Sampath, 1976). From the reports (1949-1976) of the above authors, it would appear that the prospects of fish seed exploitation are very poor since the reported percentage of seed occurrence was only about 30-40%. It is likely that such a low yield may be due to the prevalence of unfavourable environmental conditions in these estuaries. Since estuaries are very productive zones and are ideal sites for fish farming (Odum, 1970; Espey and Ward, 1972; Kurian, 1973 and Ganapati, 1975), it is likely that the poor yield may be due to environmental pollution. More recently, Rao and Madhupratap (1981) pointed out that estuaries will become irreversably damaged if corrective measures are not undertaken. For such remedial measures, it is important to have sufficient data on the behaviour of the river over a period of time. Therefore, it is the purpose of this investigation to carry out an extensive estuarine fish-seed survey in order to obtain the necessary base-line data on seed abundance. It may be pointed out that in a few estuaries such as River Cooum and River Adyar, some improvement schemes have been implemented by the Government of Tamil Nadu. One such step includes a reduction in the volume of untreated sewage flowing into the estuarine regions besides maintaining the continuity of the river mouth with the sea. Under these circumstances, it was felt worthwhile to reexamine the changes if any, in the abundance of commercially important and exploitable cultivable fish seed in the coastal estuaries of Madras.

In reviewing the previous survey on fish seed resources, it is noted that assessment has been made only for limited periods and no attempt has been made to obtain data on the regional, seasonal and species-wise abundance of fish seed. Therefore, it was thought desirable to gain an understanding of the seasonal abundance of a selected few commercially important cultivable fishes together with the physico-chemical factors in order to compare the biocoenology of the estuarine ecosystem. Further, attention was paid to record the incidence of other fishes and prawns so as to obtain a picture on the species to species ratio. It is felt that a knowledge on the relationship among the natural composition of commercially important fishes, prawns and other fishes may be valuable for the polyculture of fishes by modern fish culturists and private entrepreneurs.

Another causative factor that bears a direct relationship with the seed abundance is the condition of the river mouth. The estuaries of coastal Madras do not remain in constant continuity with the sea coast throughout the year. They were reported to be cut off from the open sea for a period ranging from 6 to 9 months (Chacko, 1956; Abraham, 1962; Ganapati, 1964; Evangeline, 1968; Evangeline and Subbiah, 1969; Evangeline et al., 1969; Krishnan and Sampath, 1976). It has been reported that the long shore drift on the open coast frequently closes the river mouth. As a result, acute sullage problems arise in most of the coastal rivers where a minor portion of the untreated sewage is allowed to flow into the river system. Therefore, it is reasonable to expect severe oscillation in the physico-chemical characteristics of the coastal ecosystem.

If the fluctuations in the abiotic regime is detrimental to the biotic components, then there may be correlated changes in the abundance of fish seed resources. On this basis, an attempt has been made to relate the fish seed abundance with the condition of the mouth of the river whether open or closed. It is hoped that such an integrated survey would provide information for formulating guide lines for effective utilization of natural estuarine resources.

Among the commercially important cultivable fishes, mullets are considered as an important source of human food. *Liza macrolepis* (Smith), commonly called the grey mullet, is an estuarine euryhaline fish belonging to the family Mugilidae. It is one of the most annually abundant species among the mullets of the coastal and estuarine waters around Madras region both in terms of its number and biomass (CMFRI/ CIFRI, 1975, 1978). Moreover, it is an important member of the estuarine community and a major component in the flow of energy through the ecosystem (Odum, 1968). The ability of this grey mullet to survive in a wide range of environmental conditions is well documented by the reviews of Thomson (1954, 1966), Kinne (1964), Luther (1967) and Pillai (1972). Some aspects of the biology of this grey mullet have been studied by many earlier workers (Luther, 1962, 1963; Jhingran and Natarajan, 1969 b, Rangaswamy, 1980). In recent years, there have been many attempts to culture mullets in estuaries, backwaters and coastal waters of India in order to (i) utilize huge areas which have possibilities for aquaculture development (ii) to increase the production of animal protein to meet the needs of the fast growing population (iii) to produce high priced commodities for export and consequently for earning foreign exchange and (iv) creating employment opportunities (Jhingran, 1969, Pillai, 1972; Qasim, 1975; Varghese, 1975; Silas et al., 1976; Rajalakshmi, 1980 and Venkataraman et al., 1980).

In recent years, there has been a phenomenal increase in the population of Madras. The Tamil Nadu Slum Clearance Board has constructed many houses along the coast of Madras TNSCB, 1978). Moreover, the Madras Metropolitan Development Authority has paved the way for the construction of many houses for the low and middle income groups and has provided plans for the construction of many private industries in the urban areas such as George Town, Triplicane, Tondiarpet, Chintadripet, Egmore, Purasavalkam, Sembiam, Perambur, Mylapore, Nungambakkam, Thiyagarayanagar, Kodambakkam, Nandanam, Ayyanavaram, Kotturpuram, Adyar, Saidapet, Guindy and Nandambakkam (MMDA, Plan 1973). Madras is also an industrialized city. Major industries like Hindustan Teleprinters, Indian Drugs and Pharmaceuticals, Madras

Surgical Instruments, Britannia Biscuits, numerous other private industries engaged in electroplating, plastics, battery and electrical goods manufacture, textile, chemical industry, pigment colouring and paint factories, motor spare parts manufacturing units, private hospitals and government institutions like Guindy Engineering College and King Institute, Slaughter houses, many cemetries and crematoriums are located around the Adyar estuary. Further, it has been estimated that about 7,75,000 litres/day of industrial effluents carrying heavy metallic elements are discharged into this river system (Sornavel, 1978). Another source of contamination that poses a danger to the aquatic life in this river is the discharge of untreated domestic sewage which adversely affects the water quality. The quantum of domestic sewage output in the Madras Metropolitan area has been estimated to be about 51 million gallons/day and about 1.8 million gallons/day is allowed to flow into the Adyar river system (TNWSSB, 1980). The potential for use of sewage waste water in aquaculture is still largely unutilized, though it is practiced with success in some countries and offers good prospects for the future (FAO, 1971 and Allen, 1972).

It has been known for many years that concentration of heavy metals is significantly higher in the marine biosphere (Waldichuk, 1974). Today, additional quantities of heavy metals are being added to estuarine and coastal regions from agricultural and industrial wastes, hospitals, domestic sewage and from the polluted atmosphere (Foyn, 1965; Ludwig and Storrs, 1970 and Ackefors, 1971). Heavy metal pollution is one of the consequences of industrialization. At sufficiently high concentrations, heavy metals are toxic to marine and estuarine organisms and to their consumers at higher trophic levels including man (Katz, 1973). Doudoroff and Katz (1953) reviewed the literature on toxicity of industrial wastes to fishes. Eisler et al., (1978) have reviewed the biological effects of heavy metals on aquatic organisms. Phillips (1977) reviewed the literature on the biological indicator organisms which have been used to monitor trace metal pollution in marine and estuarine environments. Fish apparently can accumulate mercury compounds more than other aquatic organisms either directly from sea water or indirectly through food chain (Bryan, 1976 a, 1979).

The many substances regarded as environmental contaminants may be grouped under two broad categories as (i) essential and (ii) non-essential for life. Whether essential or not, inorganic or organic, many potentially toxic substances possess properties which make them readily available for accumulation by marine organisms and this is the basis for much of the present day concern about pollution (Bryan, 1979). The current alarm of heavy metal pollution in the aquatic environment is due to the tragedy of Minimata and later Niigata in Japan. These tragedies resulted in an awareness of the problem of bioaccumulation of mercury and cadmium by aquatic organisms and spured research on the levels of the metals in aquatic organisms (Waldichuk, 1974).

Among the many toxic heavy metallic elements, mercury and cadmium are considered to be the most toxic metals. It has been shown that over accumulation of mercury and cadmium in the aquatic organisms is not only harmful to that organism but to predators as well (Krenkel, 1973). Many authors have assessed the concentration of mercury in various tissues of fishes inhabiting the open sea, coastal areas and estuaries (Westoo, 1966; Backstrom, 1967; Jensen and Jernelov, 1969; Ackefors et al., 1970; Somayajulu and Rama, 1972; Doi and Ui, 1973; Taylor, 1973; Holden, 1973; Tejam and Halder, 1975; Cugurra and Maura, 1976, Matsunga, 1978, Ramamurthy, 1979; Stoeppler and Nurnburg, 1979 and Kureishy et al., 1980). Similarly, the concentration of cadmium in different tissues of fishes have been estimated by many earlier workers (Goldberg, 1962; Eisler and LaRoche, 1972; Portmann, 1972; Harve et al., 1973; Won, 1973; Topping, 1973; Harms, 1975;

Phillips, 1977; Stoeppler and Nurnburg, 1979 and Westernhagen *et al*., 1980). Qasim and Gupta (1980), while reviewing the existing knowledge on the incidence and implication of heavy metal toxicants in fishes of the Arabian sea, Bay of Bengal and Indian Ocean have pointed out the importance of carrying out further studies in this area of interest. It is felt that such a knowledge may help to formulate guidelines for culture practices of mullets besides the preservation of life in the estuary.

A preliminary investigation was carried out to assess the concentration of some of the heavy metals in mullets of Adyar estuary. Such a study indicated a relatively high bioaccumulation of heavy metals. For instance, the bioaccumulation of the heavy metal such as mercury in fishes of Indian Ocean is known to be in the range of 0.06 ppm (gills), 0.04 ppm (liver) and 0.10 ppm (muscle). But mullets, *Liza macrolepis* (Smith) in Adyar estuary were found to have a concentration of 0.10, 0.09 and 0.12 ppm in gills, liver and muscle tissues respectively which is about 40%, 50% and 20% higher than the reported concentration. Stoeppler and Nurnburg (1979) reported that the bioaccumulation of cadmium in various tissues of fishes from clean marine environments was in the range of 0.31 ppm (gills), 0.34 ppm (liver) and 0.70 ppm (muscle). On the contrary, mullets

<u>Liza macrolepis</u> (Smith) from Adyar estuary were found to have a concentration level of 0.74 ppm, 0.78 ppm and 1.55 ppm in gills, liver and muscle tissues respectively which is about 41%, 44% and 45% higher than the reported levels. It stands to reason that mullets have accumulated the said heavy metals from the ambient environment. Consequently, it is inferred that high levels of mercury and cadmium in the ambient water may be due to the discharge of industrial, and domestic sewage waste into the Adyar estuary. Therefore, the behavioural toxicology of mullets were studied with special reference to mercury and cadmium.

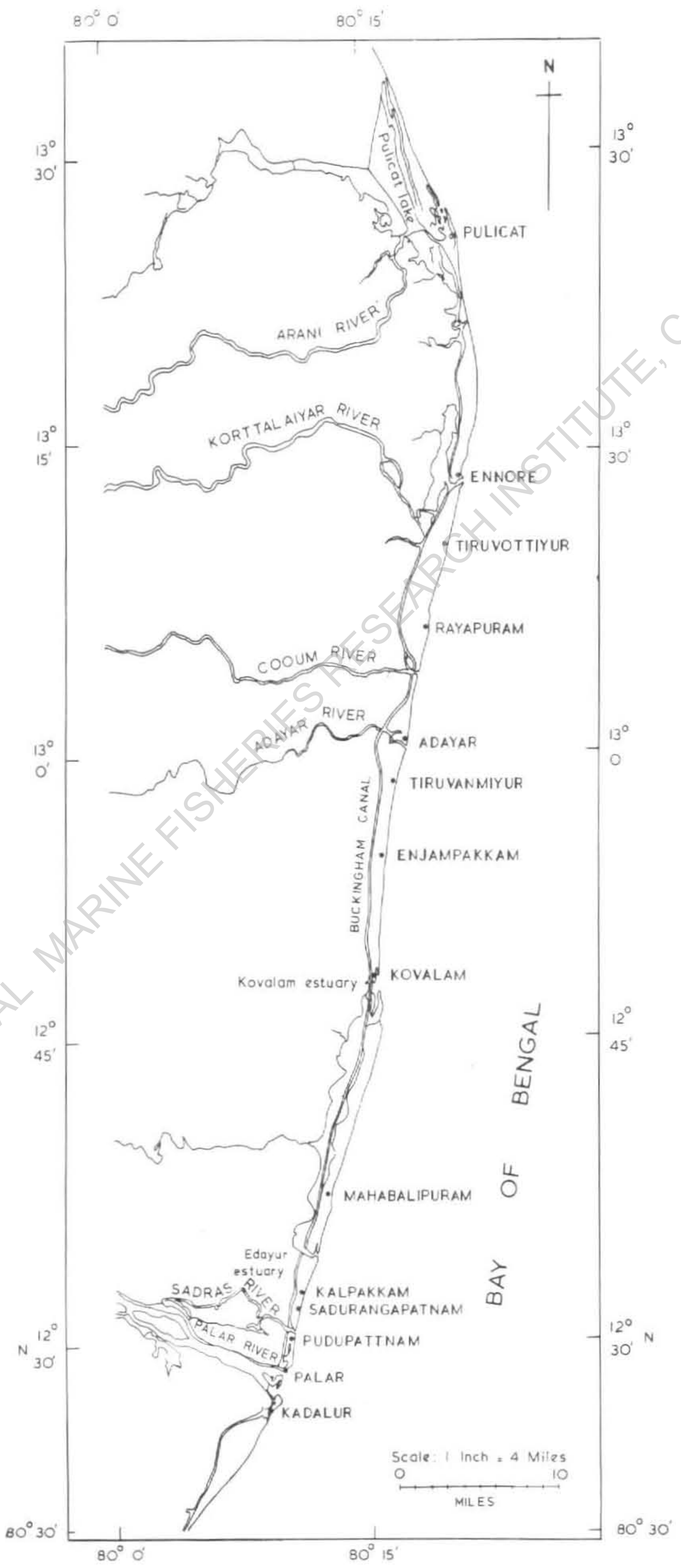
Marine and estuarine ecosystems can tolerate domestic sewage and industrial effluents not only by reason of the rapid dilution that occurs but also because of those biological processes which degrade, detoxify or sequester contaminants. While the capacity of biological systems to adapt varying loads of such materials is considerable, a guiding principle in environmental management is that the pollution load does not exceed the threshold level, since small increases above the maximum tolerable load may lead to disproportionate effects on biological processes (Stebbing, 1979). With the growing interest in aquaculture, a study on the heavy metals has an important practical application. Not only are they important in terms of water quality but also they are essential from the view point of product acceptability (Waldichuk, 1974). Hence, besides measuring the concentrations of these metals in fishes and other aquatic organisms, there is a need to study the effects of metals on the organisms. This will require careful evaluation of the effects of heavy metals on the ecophysiology, histology, biochemistry and behavioural responses of fishes. Further, morphological changes such as fin erosion were also noticed in mullets caught from Adyar estuary. Sindermann (1976, 1979); Ziskowski and Murchelano (1975), Wellings <u>et al</u>., (1976) Sherwood and McCain (1976) and Sherwood (1976) have suggested that fin erosion disease is an indication of heavy metal pollution in aquatic ecosystem. Since, in Adyar estuary, physiological effects begin to be noticed in fishes, it is felt worthwhile, to study the biological responses to mullet <u>Liza macrolepis</u> (Smith) to a chosen heavy metals such as mercury and cadmium.

Studies on the physiology and behavioural responses of marine and estuarine organisms to pollutants often necessiate the establishment of acceptable concentrations of the pollutants (Henderson, 1957; Anderson, 1971; Preston and Wood, 1971; Tarzwell, 1971; Sprague, 1971, 1976; Eaton, 1973; Vernberg and Vernberg, 1974; Vernberg, 1975; Vernberg <u>et al</u>., 1977; Basak and Konar, 1977; Duthie, 1977; Kimerle, 1977 and

Eisler, 1979). Such levels are often referred as "safe level concentrations" or "allowable/permissable limits". In these concentrations, fishes will live, grow and reproduce normally. To arrive at a conceptial frame work for conducting hazard assessment, it is necessary to acquire information on the inherent toxicological properties of the chemical as well as knowledge on judgement concerning safety/risk associated with the prevalence of the said pollutants in the environment. Cairns et al., (1979) defined safety/risks as "scientific judgement" regarding the probability of harm to the aquatic environment resulting from known or potential environmental concentration (page 85). Thus, a pollutant is said to be safe if attendant risks are judged as acceptable. Therefore, the overall policy in monitoring the coastal ecosystem is to estimate the maximum allowable concentrations of a potential toxicant which are not harmful to the aquatic biota with continuous exposure. Such data have provided useful information in setting water quality standards (Tarzwell, 1971) and careful management and protection of resources from the stand point of the welfare of man (Stebbing, 1979 and Preston, 1979). Therefore, it was thought worthwhile to carry out bioassay studies to determine the allowable waste concentrations in the aquatic environment and also to apply a suitable "application factor" in the short term acute bioassay tests so as to estimate "safe levels" under conditions of long exposure in the environment. In the face of industrialization, discharge of heavy metallic toxicants are of great concern in management of marine and estuarine ecosystems (Sindermann, 1976 and Dalziel, 1979). Hence knowledge of the 'safe level' concentrations of the heavy metals in the present study with reference to mullet, *Liza macrolepis* in Adyar estuary will be highly useful to the modern fish culturists and entrepreneurs. Therefore, in view of the increased use of mercury and cadmium in the industrial activity around Adyar estuary, it is of interest to obtain base line information on the toxic effects of mercury and cadmium on the behaviour, physiology, histology, correlated biochemical changes and bioaccumulation in *L. macrolepis*. Further, it was felt that such a study would provide information whether there is any detoxification mechanisms present in fishes. If so, the suitability of using mullet, *Liza macrolepis* (Smith) as bioassay material will be of immense use to fish culturists besides heavy metals pollution monitoring.

FIG. 1

MAP SHOWING THE LOCATION OF ESTUARIES IN AND AROUND MADRAS REGION WHERE MULLET PRAWN AND OTHER FISH SEED RESOURCES SURVEY WAS CONDUCTED FROM APRIL 1978 TO MARCH 1979



2.0.0 MATERIAL AND METHODS

2.1.0 Survey on the seed resources of mullet *Liza macrolepis* (Smith), prawn, *Penaeus indicus* Milne-Edwards and other fishes from the coastal estuaries around Madras.

A survey on the abundance of mullet, *Liza macrolepis* (Smith), prawn, *Penaeus indicus* Milne-Edwards and other fish seed was conducted during the period from April 1978 to March 1979. The following eight estuaries were surveyed: Pulicat, Ennore, Cooum, Adyar, Kovalam, Edayur, Sadras and Palar (Fig.1). Jhingran *et al*., (1970) have reviewed various types of gear used for the capture of fish seed. The method followed by Evangeline and Sudhakar (1972) and Ramanathan and Jayamaha (1972) were used in the present study. Accordingly, a nylon mosquito drag net was designed (2 mm mesh size: dimension 4 x 3 x 1 m) and attached to two poles in order to facilitate easy operation of the net (Fig.2). The net was draged by two men for a distance of about 50 metres. The entire operation took about 10 minutes. In stations where sampling was found difficult, the operation was limited to 25 metres covering about 5 minutes. At each survey centre 5 to 8 drag net operations were made.

Survey work was carried out in the early morning hours of the day. In each catch, the number of fry and fingerlings of mullets and prawns and other fishes were counted and the total length was measured to the nearest mm (Fig.3). Based on the operational time, volume of water filtered, the area covered, the number of fry and fingerlings per net/hr was estimated (Bose and Venkatesan, 1980). It may be mentioned that fry and fingerlings can be defined and grouped according to their length. Juveniles upto a length of 35 mm were considered as "fry" and specimens ranging above 35 mm to 150 mm in length were treated as "fingerlings" (Jones, 1950 and Alikunhi, 1957). Each estuary was surveyed twice in a month. Monthly data presented in Tables 1-8 represents the mean values of fortnightly collections.

2.1.1 <u>Hydrological methods</u>

In each of the estuaries mentioned above, hydrological data such as temperature, salinity, dissolved oxygen, p^H and water transparency were obtained. Salinity was determined using Mohr's titration method as outlined in Strickland and Parson (1965). Dissolved oxygen was estimated by Winkler's method using N/100 sodium thiosulphate solution standardised against N/100 potassium dichromate (Welsh and Smith, 1949). p^H was determined by Elico p^H meter. Water transparency was estimated by Secchi-disc method (Baylis, 1933). Monthly data presented in Tables 20-27 represents the mean values of fortnightly analysis of water samples.

FIG. 2

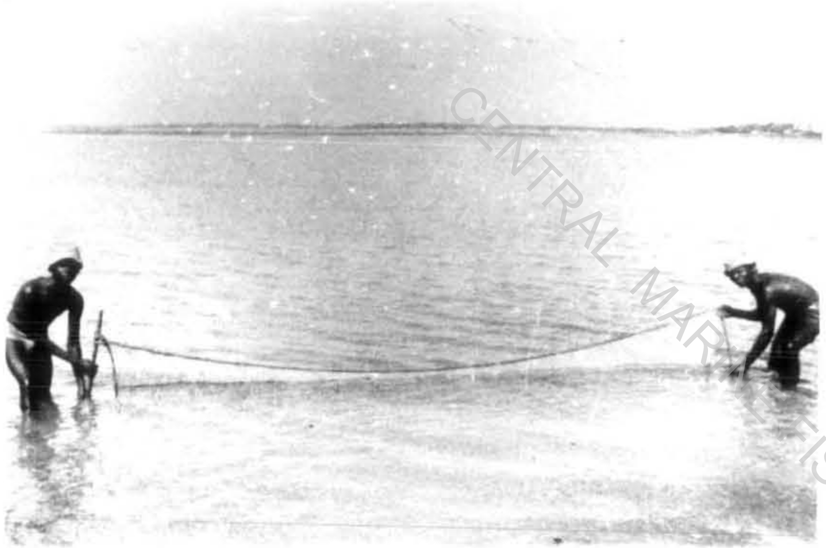


FIG. 3

FIG. 4

FIG. 5

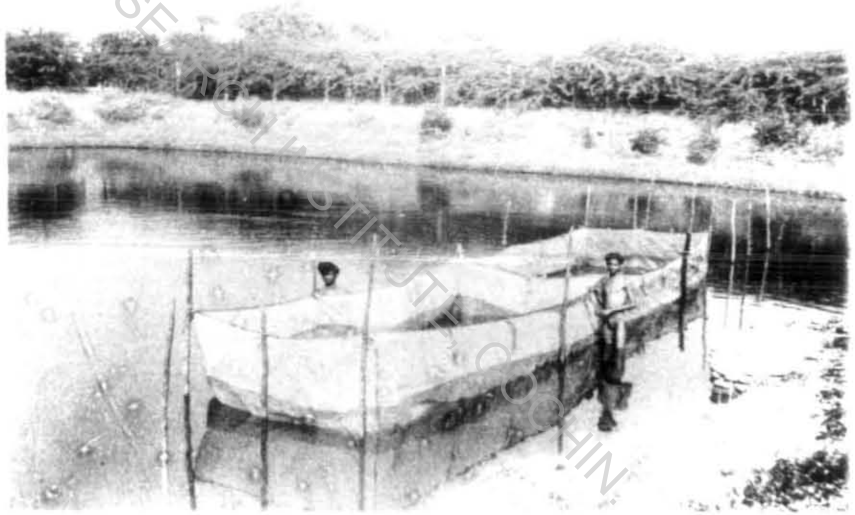


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Fig.2 Operation of the drag net by two men.

Fig.3 Photograph showing the catch of fish and prawn seed.

Fig.4 Mullet catches from a 'Periya bandha valai' operation in Adyar estuary, Madras.

Fig.5 Photograph showing the nylon net lined 'happa' erected in the fish pond for the purpose of stocking mullets, *L. macrolepis*.

2.2.0 Collection, transport and rearing of mullet, *Liza macrolepis* (Smith)

Live mullet fingerlings of the length group 80-85 mm weighing between 5 to 5.5 gm were collected from "Periya bandha valai" (gill net) and 'drag net' operations near the mouth region of the Adyar estuary (Fig.4). They were then transported to the Brackishwater Fish Farm, Santhome, Madras (Tamil Nadu Fisheries Department) situated close to the proposed field location. Mullets were stocked in the nylon net lined "happa" (3 x 2 x 1 m) erected in the fish pond (Fig.5) and the fingerlings were fed daily with ground nut paste and algae (*Enteromorpha* spp., and *Chaetomorpha* spp.) in addition to the natural plankton food (Alikunhi, 1957).

2.2.1 Bioassay/aquaculture experiments under field conditions

Falk (1973) carried out bioassays with fish in field locations using specially designed cages in order to assess water pollution. While following his method, in the present study suitable modifications to fit local conditions were made with regard to the size and nature of the cages used. Nylon net (2 mm mesh size) lined cage with a dimension of 2 x 1 x 1 m was designed. The top side of the cage was left open for the release of mullet fingerlings. A second larger cage (2 x 2 x 1 m) was also fabricated in order to

FIG. 6

FIG. 7-A

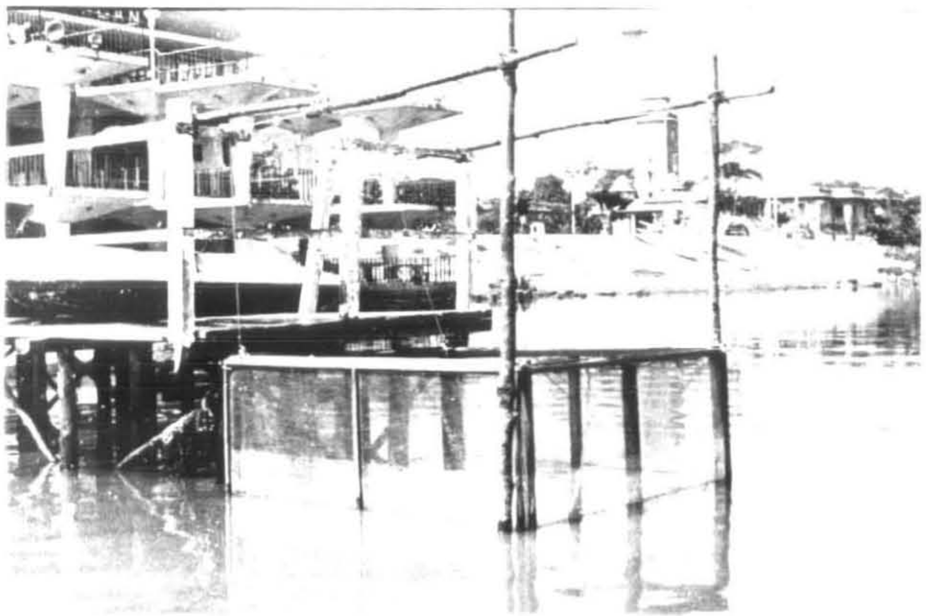

FIG. 8-B

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Fig.6 Floating fish cage used for field bioassay/aquaculture experiments near 'Chettinad Bungalow' in Adyar estuary, Madras.

Fig.7-A Floating fish cage used for field bioassay tests in Cooum estuary, Madras.

Fig.8-B Acclimatisation of mullet fingerlings *L. macrolepis* for laboratory bioassay tests.

study the effect of stocking density and cage size. The cages were erected near the "Chettinad Bungalow" situated about 0.8 km from the mouth of the Adyar estuary, Madras (Fig.6).

After about a week of acclimatization, mullet fingerlings were released in the experimental cages erected in the Adyar estuary. Growth and survival rates were estimated for a period of six months from January to July, 1980 without giving any supplementary food. Using two different cages, field bioassays were carried out in order to assess the effects of stocking density on growth rate and survival.

Similarly, bioassay tests, under field conditions, using a nylon net lined cage (2 x 1 x 1 m) were also undertaken in the Cooum estuary, Madras (Fig.7 A). The experimental site was located near Marina Boat Club situated about 0.4 km from the mouth of the Cooum estuary. Mullet fingerlings were collected from Adyar estuary and transported to Cooum estuary test sites after a period of one week acclimatization in the Brackishwater Fish Farm, Santhome, Madras. Time Vs mortality rates of mullets during different tidal phases of the estuary were assessed (Fig.7 B).

Hydrological characteristics such as temperature, salinity, dissolved oxygen, p^H and water transparency were determined concurrently.

FIG. 7- B

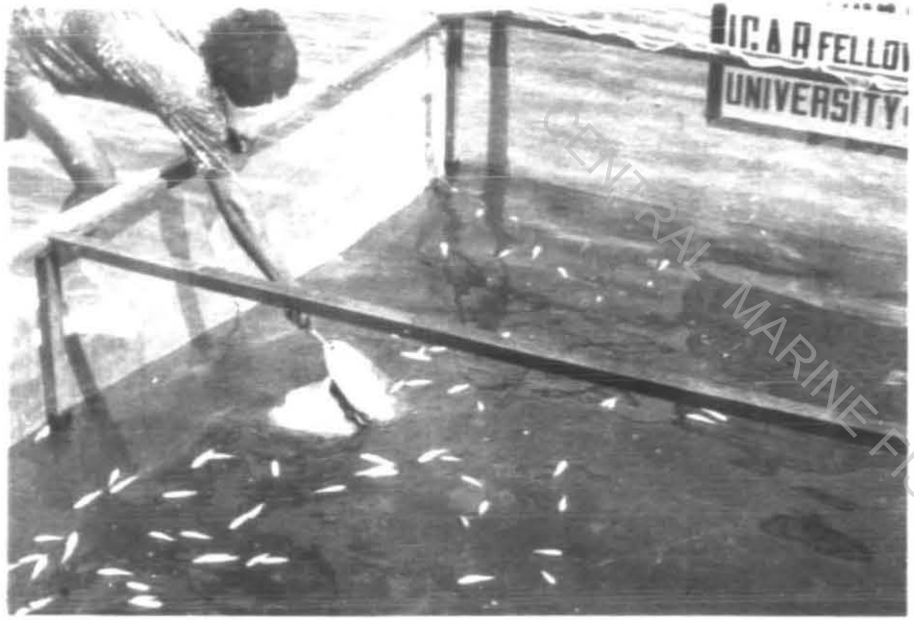

FIG. 37 - B

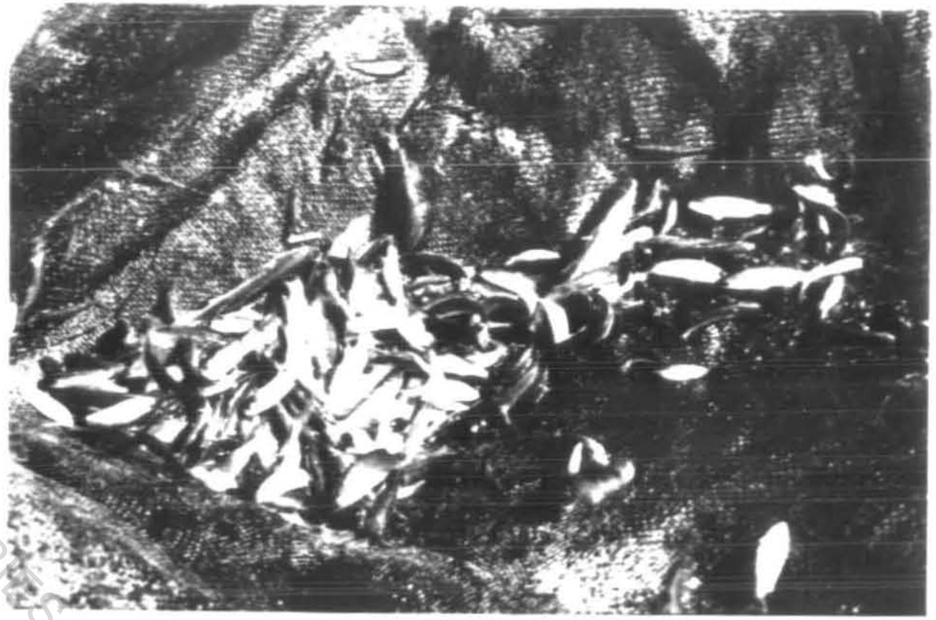

FIG. 37- A

FIG. 8 - A

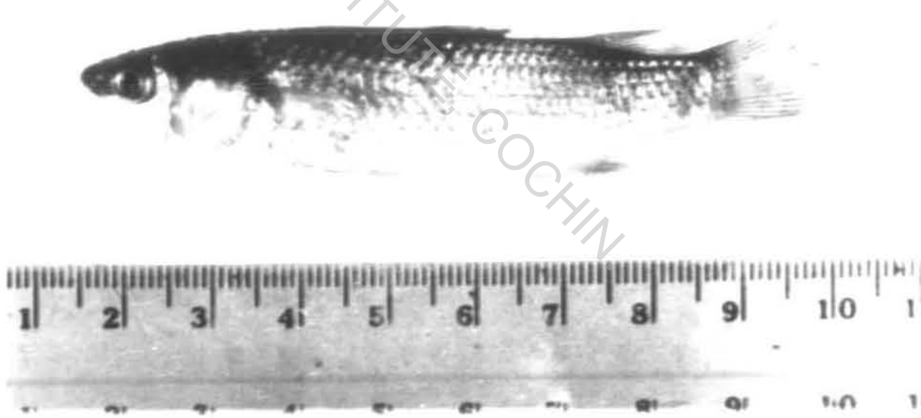

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Fig.7-B Floating dead mullets, L. macrolepis during field bioassay tests in Cooum estuary, Madras.

Fig.37-A Cultured mullets L. macrolepis in the cages - Adyar estuary, Madras (Refer page 70).

Fig.37-B Cultured mullets, L. macrolepis in the cages - Adyar estuary, Madras (Refer page 70).

Fig.8-A Photograph showing the size of mullet L. macrolepis used for all the bioassay/aquaculture experiments.

2.3.0 Bioassay tests under laboratory conditions

Static bioassay for 96 h period was conducted under laboratory conditions in accordance with the methods recommended by the committee on Methods for toxicity tests with aquatic organisms (EPA, 1975).

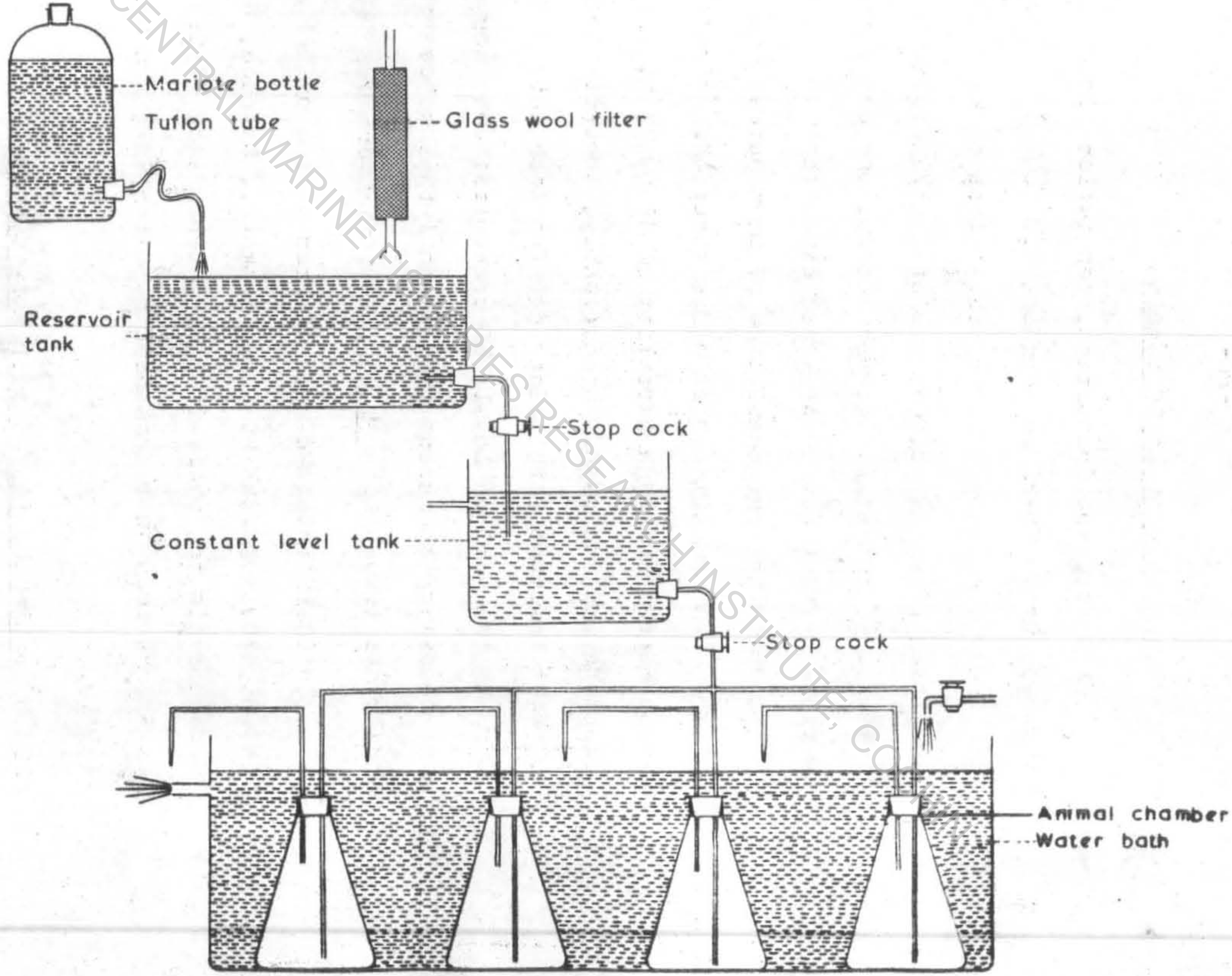
Live mullet fingerlings collected from Adyar estuary were stocked in the "happa" erected in fish ponds as mentioned earlier. They were fed with ground nut paste, algae (Enteromorpha spp. and Chaetomorpha spp.) in addition to the actual plankton present in pond water. Later, fingerlings in the length group of 80-85 mm (Fig.8 A) were acclimated in fibre glass tanks (60 x 60 x 48 cm) to a salinity of 15‰ (Fig.8 B). The physico-chemical conditions of the water used for all the toxicity tests were also determined (Table 43).

2.3.1 Preparation of stock solutions

Stock solutions of the selected heavy metal toxicants such as mercury and cadmium were prepared with deionised water following the dilution technique adopted by the committee on methods for toxicity tests on aquatic organisms (EPA, 1975). The chloride compounds combined with mercury and cadmium were deducted and actual concentration levels was taken into consideration for all toxicity assessment (Eisler, 1971 and Wobeser, 1975).

FIG. 9

CONTINUOUS FLOW BIOASSAY EXPERIMENTAL SYSTEM



2.3.2 Evaluation of Lc 50 levels

Prior to experimentation, ten mullet fingerlings of the size group 80-85 mm weighing 5.0 to 5.5 gm were starved for a day and released into fibre glass tanks containing 50 litres of water at the rate of 1 gm/litre (Sprague, 1973). A series of ten static bioassay tests was conducted with mullets using a series of known concentrations of mercury and cadmium and the occurrence of mean percentage mortality of 20%, 50% and 80% for 24 h was recorded. Similarly, the above mean percentage mortality at 48 h, 72 h, and 96 h after exposure was recorded. Concurrently, control experiments without toxicant were maintained for each set of experiments. Data on the various levels of concentrations and mortality are necessary to assess the median lethal concentrations of toxicants (Doudoroff et al., 1951 and Sprague, 1969, 1970).

The data obtained were plotted on log probit charts (No.32,376) supplied by Codex Book Co., Norwood, U.S.A. and were used in the analysis of 95% confidence limits for 96 h Lc 50 values as recommended by Litchfield and Wilcoxon (1949).

2.3.3 Continuous flow respiratory system

Oxygen consumption was measured using a continuous-flow system described by Welsh and Smith (1949) and O'Hara (1971) and modified by Lingaraja et al., (1980). The continuous flow set up is given in Fig.9.

The experimental set up consisted of a reservoir tank to hold a large volume of water. Water from the reservoir tank was allowed to flow into a constant level tank to which four animal chambers were connected. One animal chamber was kept without any fish (blank) so as to obtain the initial level of dissolved oxygen. The capacity of each animal chamber was about 2 litres. Arrangements were made to aerate the water in the constant level tank. Estuarine water (salinity 15‰) was filtered into the reservoir tank through a glass column, packed with glass wool. The animal chambers were kept in a water tank with running water system throughout the course of experiment in order to regulate the water temperature at 29° C $\pm$ 1° C. The rate of flow of water through each animal chamber was regulated with suitable glass nozzles. The rate of flow of water in each animal chamber was checked before taking water samples for dissolved oxygen estimation. Water samples were collected at an interval of every hour during the first 24 h and then once in every 6 h upto 96 h period. Each experiment was conducted for a total period of 96 h. Dissolved oxygen was estimated by the Winkler's method as mentioned earlier.

In order to find out the effects of heavy metals such as mercury and cadmium at 96 h Lc 50 levels on respiration, a second set of continuous flow system was designed as described above. Mullet fingerlings were allowed to respire in fresh and aerated estuarine water saturated with dissolved oxygen for a period of 6 h. Immediately the experimental test solution was allowed to flow from the dosing apparatus into the reservoir tank. The experiment was then continued as described earlier. Concurrently, the respiratory pattern of three fishes not exposed to mercury and cadmium treatment was studied using the other continuous flow set up.

2.4.0 Histological methods

Mullet fingerlings treated at 96 h Lc 50 levels of mercury (360 ppb) and cadmium (2940 ppb) in 96 h static bioassay test were sacrificed for the purposes of histopathological study. Tissues of gills, liver and muscle were fixed in 10% neutral buffered formalin. Conventional microtechniques were employed in processing the tissues for taking sections (Lillie, 1965 and Bancroft and Stevens, 1977). Sections were cut about 10 μ thickness, Sections were stained with haematoxylin and counterstained by eosin. Permanent mounts were made with DPX mountant.

2.5.0 Biochemical estimation of tissue proteins

Electrophoretic studies were made on the soluble protein fractions of the tissues of gills, liver and muscle of mullets sacrificed at 96 h Lc 50 levels of treatment of mercury and cadmium. Known weight of tissue samples were homogenized with 40% sucrose solution and centrifuged at 3000 rpm for 15 minutes. About 130 µl of the tissue sample was spotted directly on the gel using a calibrated micro-pipette.

Polyacrylamide gel electrophoresis was carried out (Davis, 1964 and Smith, 1968) using the original monomer stock and buffer systems but omitting both spacer and sample gel as has been done by Clarke (1964). Methods of preparation of gel and application of samples were those outlined by Smith (1968). Of the different percentage of polyacrylamide, 5.5% gel was found most suitable for protein separation in the present investigation (Gibert, 1971). Electrophoretic runs were made with 70 x 6 mm gel tubes at 3 mA/tube for about 50-60 minutes at 10°C until the marker bromophenol blue was 5 mm from the gel edge. Amidoblack (0.1% in 7% acetic acid in water) was used for staining the soluble proteins. Gels were destained by repeated changes in 7% acetic acid for prolonged periods and they were stored in acetic acid. The Rf values were calculated for each protein fraction in the gels according to the method by Norment et al., (1972). Scanning of the gels was carried out using "CHROMOSCAN" double beam recording and integrating densitometer (Joyece Lobel Co., England).

In order to estimate the tissue proteins quantitatively, mullet fingerlings were sacrificed at 96 h Lc 50 levels of mercury and cadmium and tissues such as gills, liver and muscle were removed and dried in a hot air oven at 70° C. The protein content of the tissue samples was determined by the method of Lowry et al., (1951) using bovine serum albumen as standard.

2.6.0 Bioaccumulation of heavy metals

For estimation of bioaccumulation levels of heavy metals, fingerlings ranging in length from 80-85 mm and weighing about 5 to 5.5 gm were collected from the Adyar estuary, Madras. After washing the fishes with fresh sea water, about 200 fingerlings were cut open and the gills, liver and muscle tissues were pooled in order to obtain about 3-5 gm of dry weight. Care was taken to wash the wet tissues with demineralised water before drying them in a hot air oven maintained at 120° C. After a period of 24 h, dried tissue samples were powdered and digestion was carried out with nitric acid to avoid possible trace element evaporation. Such a procedure has been recommended by Doshi et al., (1969). The digested matrix of the tissue was diluted with a known concentration of nitric acid (0.01 N) and was fed to the Flame Atomic Absorption Spectrophotometer (Model AA-1100). Heavy metals such as cadmium, copper, zinc, nickel, lead and iron were analysed by the above procedure.

Mercury was estimated following wet digestion method of Uthe et al., (1970) using a mercury Analyser (Model MA-77). Tissues of gills, liver and muscle of mullets were pooled to get 5-10 gm by wet weight. The different tissues were washed with demineralised water and digested with nitric acid and sulphuric acid in the ratio of 4:1 in Bethee's apparatus. The complexion of digestion was ascertained by the retention of colour of potassium permanganate. The excess permanganate was reduced using hydroxylamide hydrochloride. The digested matrix of the tissue was diluted with known volume of distilled water and analysed by the Mercury Analyser.

2.7.0 Statistical analysis

In addition to the graphical representation, the data were subjected to statistical analysis. Statistical treatment involved in the present investigation include the following:

1. Standard deviation
2. Standard error
3. Linear regression
4. Analysis of variance
5. Probit analysis
6. Student's 't' test

The statistical methods referred to above were carried out by following the procedure outlined by Gouldon (1952), Snedecor and Cochren (1967) and Sokal and Rohlf (1969).

3.0.0 RESULTS

3.1.0 Survey of mullet *Liza macrolepis* (Smith) prawn *Penaeus indicus* Milne-Edwards and other fish seed resources from the coastal estuaries around Madras.

A survey on the abundance of mullet, *Liza macrolepis* (Smith), prawn, *Penaeus indicus* Milne-Edwards and other fish seed was conducted during the period April 1978 to March 1979 in the following estuaries: Pulicat, Ennore, Cooum, Adyar, Kovalam, Edayur, Sadras and Palar. The study brought to light the regional, seasonal and species-wise distribution and abundance of mullets, prawns and other fishes.

3.1.1 Assessment of mullet and prawn seed abundance and the stock magnitude of different estuaries

3.1.1.1 Pulicat lake:

Pulicat lake (13° 26' N and 80°19' E) is located 40 kms north of Madras and confluent with the sea at about 2 kms north of Pulicat village. River Arani merges with the lake near Pulicat Village and Rivers Kalangi and Swarnamuki join the lake area at Sullurpeta in the State of Andhra Pradesh. The Buckingham canal cuts across the lake. Pulicat lake extends from Sriharikota in Andhra Pradesh to Pulicat Village in Tamil Nadu, covering a distance of about

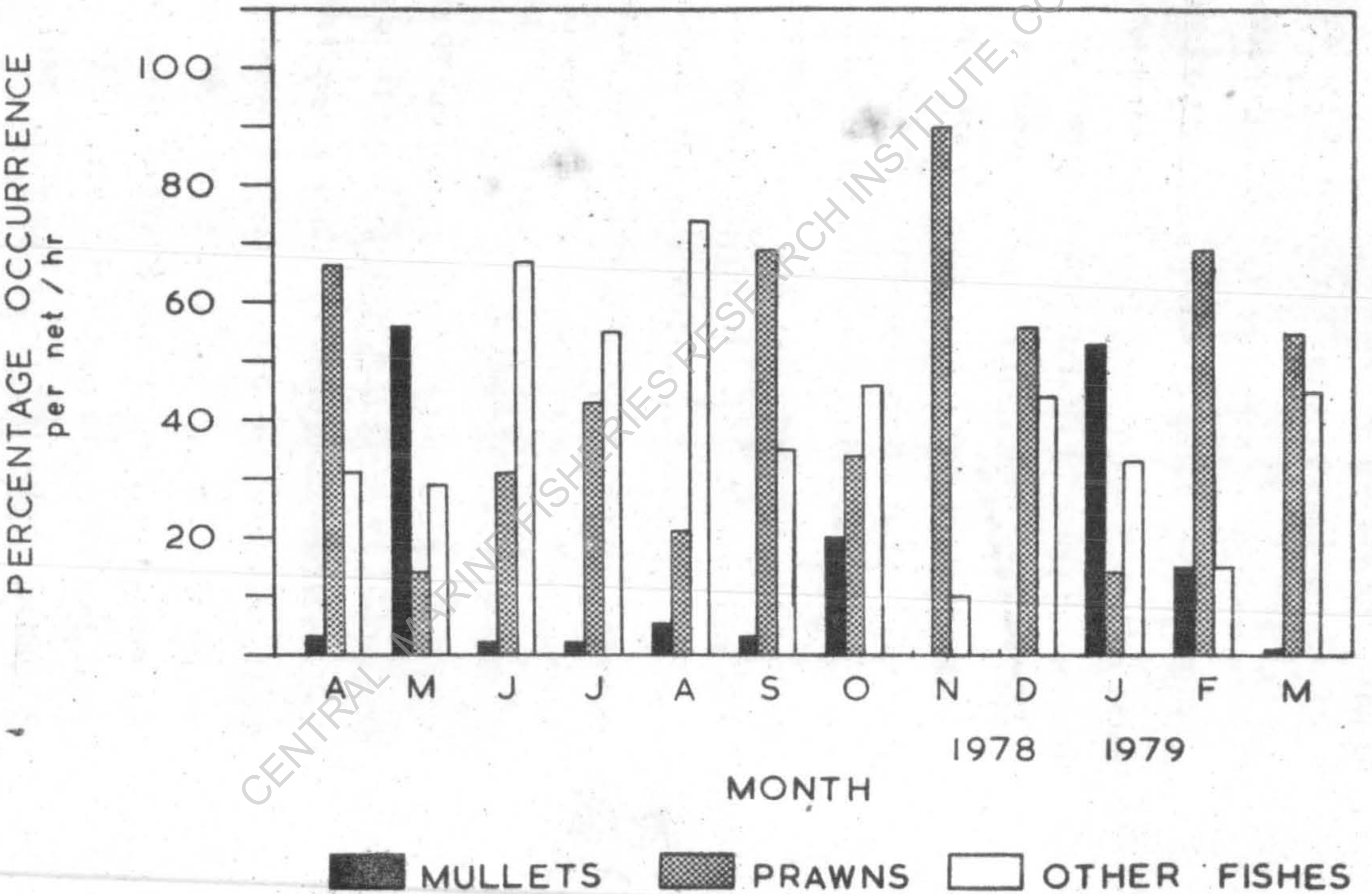
Table 1 Percentage abundance of mullet, prawn and other fish seed from Pulicat lake (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	7	285	7	2.46	188	65.96	90	31.58
May	5	1,068	600	56.18	154	14.42	314	29.40
June	8	109	2	1.83	34	31.19	73	66.97
July	8	315	6	1.90	135	42.86	174	55.24
August	5	130	7	5.38	27	20.77	96	73.85
September	6	418	12	2.87	290	69.38	146	34.93
October	5	99	19	19.19	34	34.34	46	46.46
November	5	333	-	-	300	90.09	33	9.91
December	7	237	-	-	133	56.12	104	43.88
January	6	1120	596	53.21	160	14.28	364	32.50
February	5	997	153	15.35	691	69.30	154	15.35
March	5	1311	5	0.38	720	54.92	586	44.69

* Mean of two collections

SEASONAL VARIATIONS IN THE PERCENTAGE COMPOSTION OF MULLET PRAWN & OTHER FISH SEED IN PULICAT LAKE DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 10



60 kms. The present survey was conducted in an area of about 0.30 Sq. kms from the bar mouth of the estuary.

An attempt has been made to assess the seasonal abundance of fry and fingerlings of mullet, Liza macrolepis (Smith). The total number of mullet seed in a given catch was expreseed as the percentage of the total number of organisms caught which include prawns, Penaeus indicus Milne-Edwards and other fishes. Table 1 & Fig. 10 depict the seasonal variation in the abundance of mullet seedlings. It may be seen that during the month of May, fry and fingerlings of mullets were represented in maximum numbers (56.18%), while poor representation was noted in March (0.38%). It may be pointed out that during November and December, mullets were not represented. The percentage occurrence ranged from zero to 56.18. It may be inferred that there is a seasonal abundance in the occurrence of mullets in this estuary.

It may be seen from Table 1 and Fig. 10 that fry and fingerlings of prawns, P. indicus occur throughout the year. The percentage occurrence of prawns ranged from 14.28 to 90.09. Maximum percentage of fry and fingerlings of prawns was recorded during April (90.09) while minimal percentage was recorded during January (14.28). Since fry and fingerlings occur abundantly throughout the year, it is likely that P. indicus breeds throughout the year. There is an inverse relationship between the occurrence of mullets and other fishes.

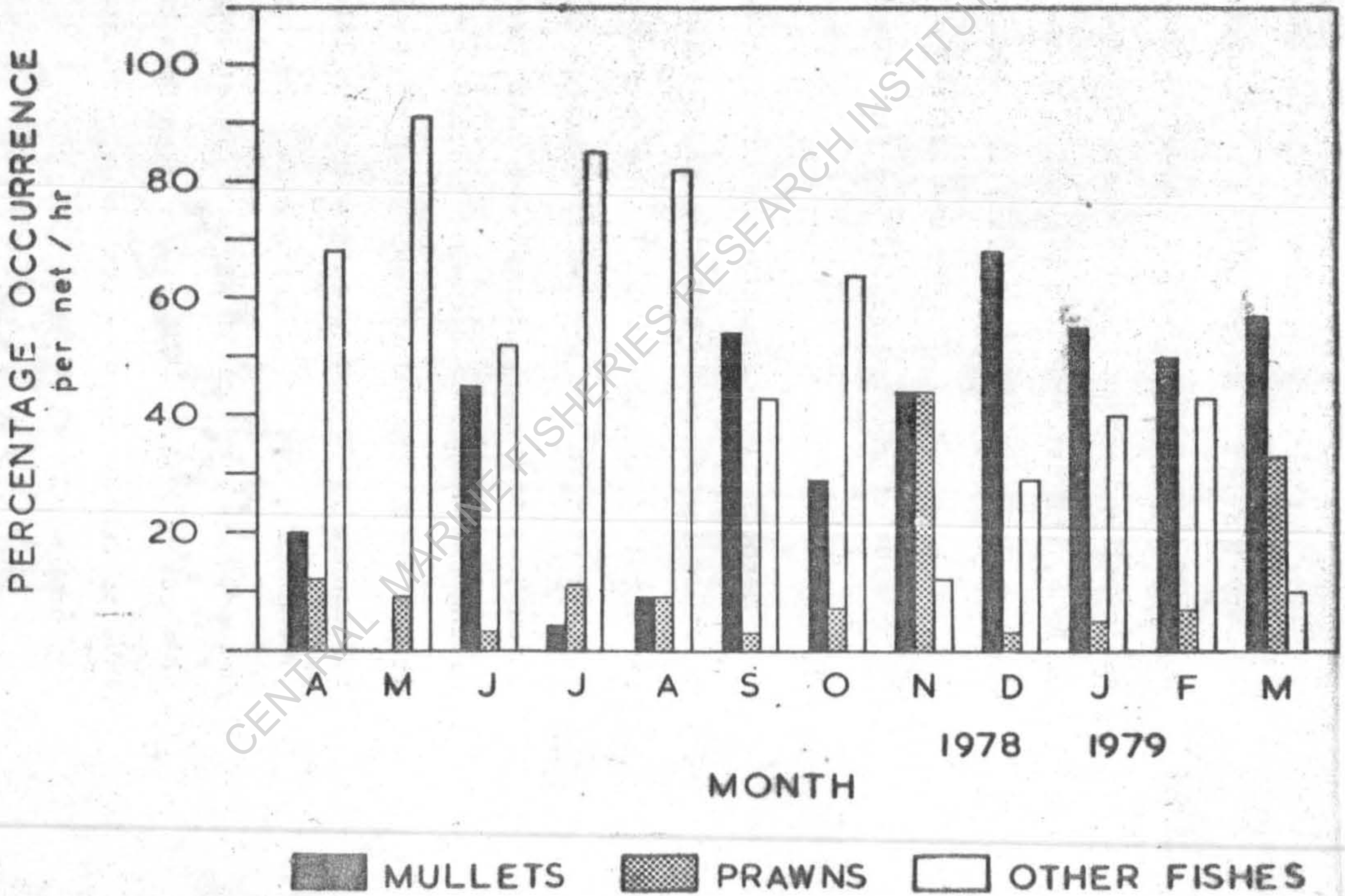
Table 2 Percentage abundance of mullet, prawn and other fish seed from Ennore estuary (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	6	367	72	19.62	43	11.72	252	68.66
May	8	309	-	-	27	8.74	282	91.26
June	8	145	66	45.52	4	2.76	75	51.72
July	7	66	3	4.54	7	10.60	56	84.85
August	8	88	8	9.09	8	9.09	72	81.82
September	6	364	196	53.85	10	2.75	158	43.40
October	5	84	24	28.59	6	7.14	54	64.28
November	5	1,395	615	44.08	612	43.87	168	12.04
December	6	252	172	68.25	8	3.17	72	28.57
January	5	542	300	55.35	24	4.43	218	40.22
February	5	1,011	501	49.55	72	7.12	438	43.32
March	5	183	105	57.37	60	32.79	18	9.84

* Mean of two collections

SEASONAL VARIATION IN THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN ENNORE ESTUARY DURING THE PERIOD OF SURVEY - APRIL 1978 TO MARCH 1979

FIG. 11



3.1.1.2 Ennore estuary

The Kortalaiyar estuary popularly known as Ennore estuary ($13^{o}14'$ N and $80^{o}20'$ E) is situated about 15 kms north of Madras. The Ennore estuary runs parallel to the sea coast and extends over a distance of 3 kms. At Ennore village, the estuary is confluent with the sea. The Buckingham canal, running parallel to the sea coast, cuts across the estuary. Survey was carried out in this estuary in an area of about 0.25 Sq. kms from the bar mouth of the estuary.

Methods as outlined in the previous section was followed in assessing the results of survey of fish seed resources of the estuary. It may be seen from Table 2 & Fig. 11 that though fry and fingerlings of mullets occurred throughout the year, significant catch was obtained only during the months of December (68.25%) and March (57.37%). It was noted that during the month of May, mullets were not represented. Minimum percentage of mullets was recorded during July, the value being 4.54. The occurrence and the percentage abundance of fry and fingerlings of mullets ranged from zero to 68.25. It may be seen from the Figure that an inverse relationship exists between the abundance of mullets and prawns.

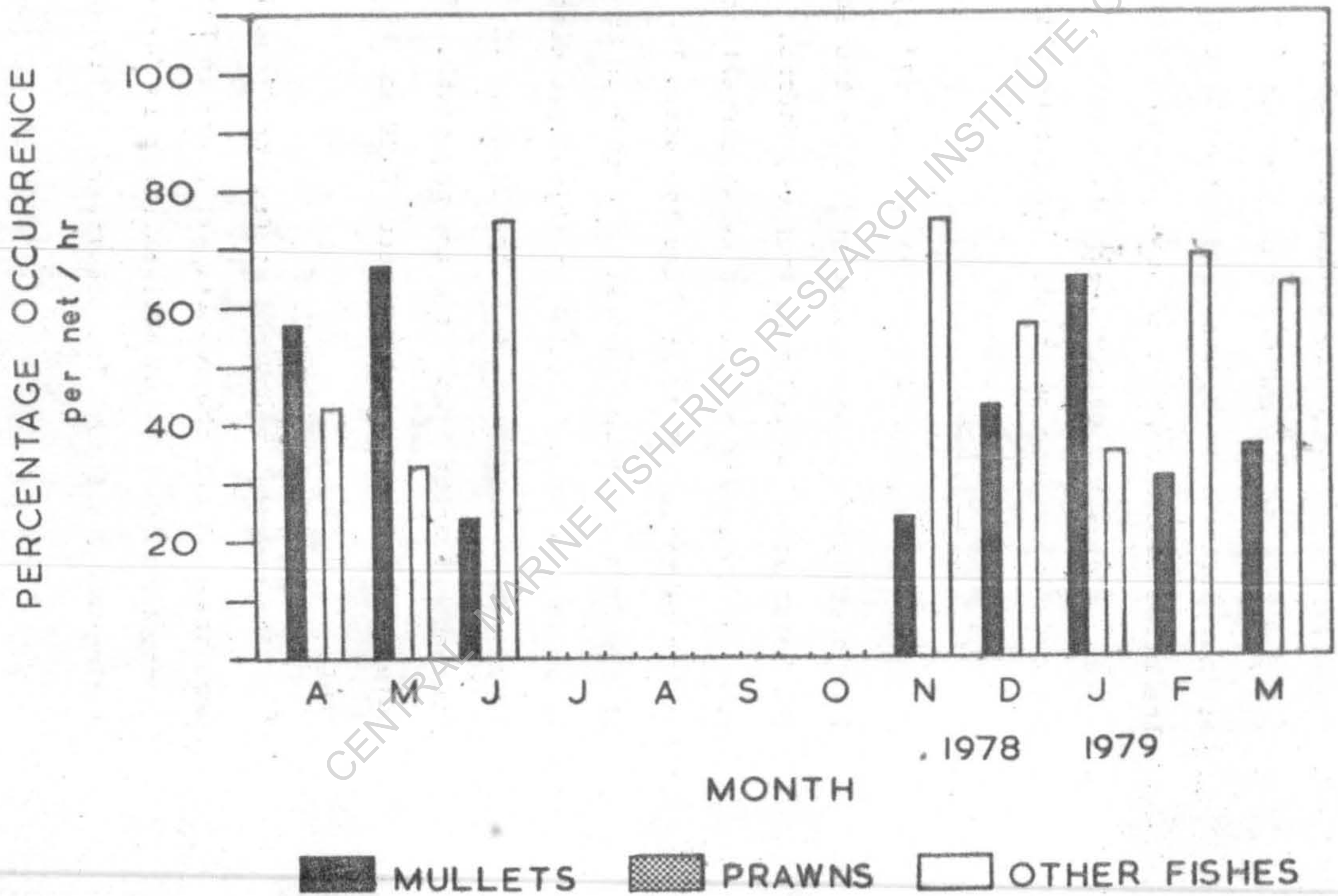
Table 3 Percentage abundance of mullet, prawn and other fish seed from Cooum estuary (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	6	120	50	58.33	-	-	70	41.67
May	7	504	336	66.66	-	-	168	33.33
June	5	234	52	24.38	-	-	182	75.62
July	-	-	-	-	-	-	-	-
August	-	-	-	-	-	-	-	-
September	-	-	-	-	-	-	-	-
October	-	-	-	-	-	-	-	-
November	6	309	75	24.27	-	-	234	75.73
December	5	143	62	43.35	-	-	81	56.64
January	5	332	217	65.36	-	-	115	34.63
February	8	504	154	30.25	-	-	524	68.91
March	5	151	55	36.42	-	-	96	63.58

* Mean of two collections

SEASONAL VARIATIONS IN THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN COOUM ESTUARY DURING THE PERIOD OF SURVEY

FIG. 12



It may be seen from Table 2 & Fig. 11 that fry and fingerlings of prawns occur throughout the year in this estuary. It may be noted that maximum abundance of prawns was recorded during the month of November (43.87%) and minimum percentage was recorded during September (2.75%). The percentage abundance of prawns ranged from 2.75 to 43.87. There is a seasonal variation in the abundance of fry and fingerlings of prawns inhabiting this estuary.

3.1.1.3 Cooum estuary

The Cooum estuary (13^{0} 4'N and 80^{0} 17' E) is located 1 km south of Fort St. George and joins the sea opposite to the University Buildings at Chepauk, Madras. The river runs perpendicular to the sea coast and extends for about 65 kms distance before it joins the sea. The Cooum River starts from a surplus channel of a tank in the village Cooum in Kancheepuram taluk of Chinglepet district in Tamil Nadu. The estuarine part of the river is limited to a distance of about 2 kms from the bar mouth. The present survey covers a distance of about 0.20 sq. kms from the bar mouth.

The seasonal abundance of fry and fingerlings of mullets were assessed and the results are given in Table 3 & Fig.12. It may be seen that the mullets occur in maximum numbers during May (66.66%). The occurrence of fry and fingerlings

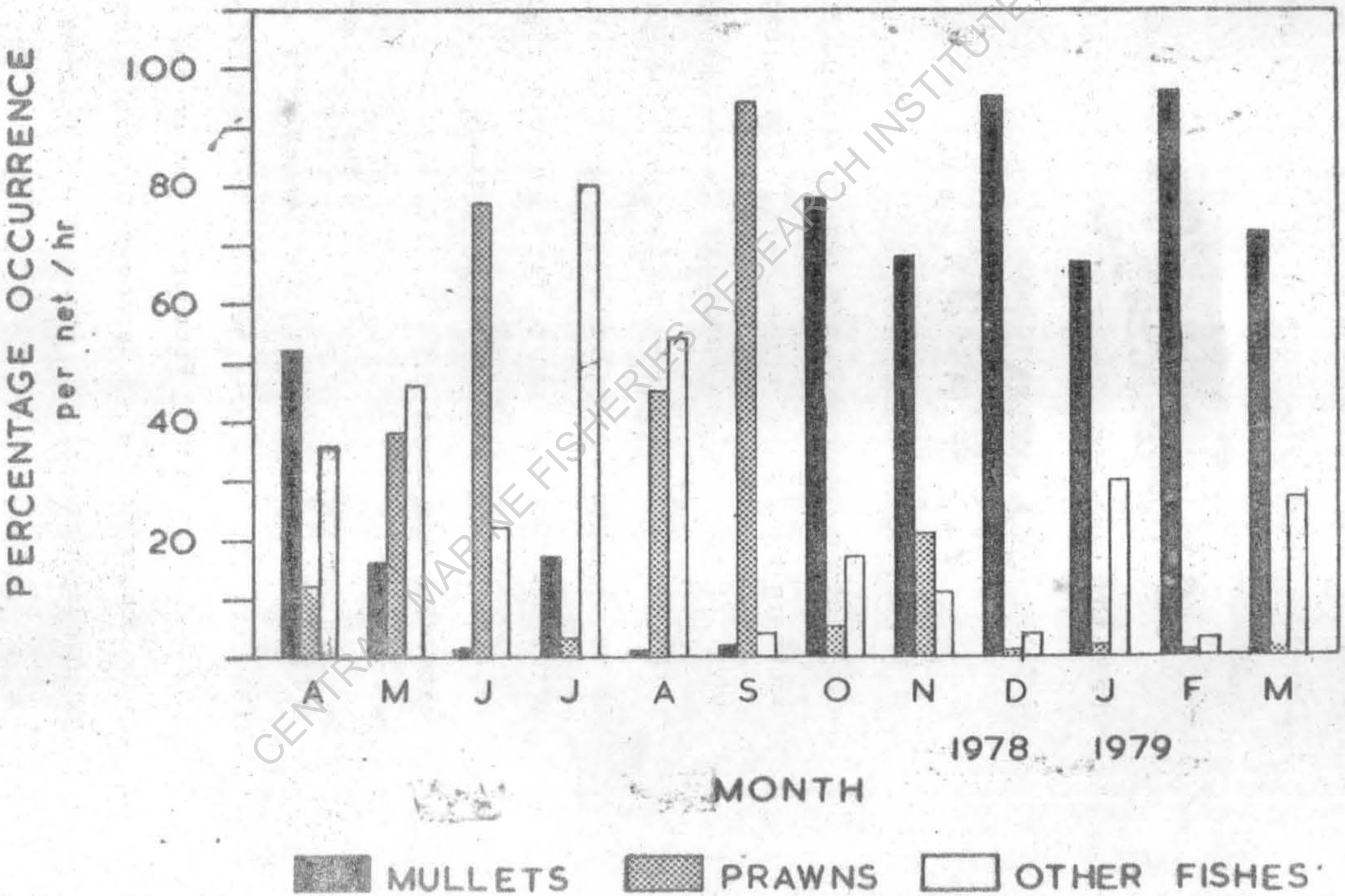
Table 4 Percentage abundance of mullet, prawn and other fish seed from Adyar estuary (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	6	526	376	52.47	62	11.78	188	35.74
May	5	5,703	914	16.02	2,145	37.61	2,644	46.36
June	5	836	7	0.84	645	77.15	184	22.00
July	6	1,466	254	17.33	36	2.45	1,176	80.22
August	5	1,600	4	0.25	732	45.75	864	54.00
September	6	532	9	1.69	498	93.78	25	4.52
October	8	3,066	2,382	77.69	171	5.58	513	16.73
November	5	400	272	68.00	84	21.00	44	11.00
December	5	9,116	8,744	95.92	16	0.17	356	3.90
January	7	1,596	1,080	67.66	24	1.50	492	30.83
February	6	7,473	7,200	96.34	24	0.32	249	3.33
March	5	1,988	1,432	72.03	24	1.21	532	26.76

* Mean of two collections

SEASONAL VARIATION IN THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN ADYAR ESTUARY DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 13



ranged from zero to 66.66%. During June to October mullets were not represented and this may be due to the formation of the sand bar at mouth of the estuary, preventing the entry of seedlings.

The fry and fingerlings of prawns were not recorded from this estuary throughout the year.

3.1.1.4 Adyar estuary

Adyar estuary (13° 1' N and 80° 17' E) extends from the Guduvancheri hills in the Kanchipuram taluk of Chinglepet district of Tamil Nadu and runs for about 30 kms towards the southern border of Madras Coast. The estuarine part of the Adyar river runs perpendicular to the sea coast and mixes with the sea near Foreshore Estate. The surplus water of the Chembarampakkam irrigation tank and the natural flood drainage water are also allowed to flow into the river system. The region selected for the present study is the estuarine area extending for about 0.50 Sq. kms from the river mouth.

It may be observed from the results presented in Table 4 & Fig. 13 that mullet fry and fingerlings occur throughout the year with two peak periods: one occurring during December and the other during February. Out of the two peaks, the peak occurring during December appears to be a minor peak when compared with the other peak occurring during February.

The range of percentage of occurrence of fry and fingerlings varied from 0.25 to 96.34. The abundance of mullets were minimum during August, the value being 0.25%. It may be seen from Fig. 13 that the seasonal abundance pattern of mullets bears an inverse relationship with the abundance of prawns and other fishes.

Although fry and fingerlings of prawns occur throughout the year, their abundance may be grouped into two sections: During June and September prawns occur in abundance with a lean period during July. During October and March, they were moderately represented. The percentage of occurrence of prawns was maximum (93.78) during September. As mentioned earlier, the pattern of abundance bears an inverse relationship with the abundance of mullets.

3.1.1.5 <u>Kovalam estuary</u>

Kovalam estuary (12^{o} 49' N and 80^{o} 15' E) is located 35 kms south of Madras and runs parallel to the sea coast. It is connected with the sea near Muttukadu Village about a kilometer from Kovalam village. In the formation of this estuary, flood waters collected from the surrounding areas constitute the estuary proper and there is no river connection. This estuary extends to a distance of about 20 kms and the area selected for the present survey extends for about 0.30 Sq. kms from the bar mouth of the estuary.

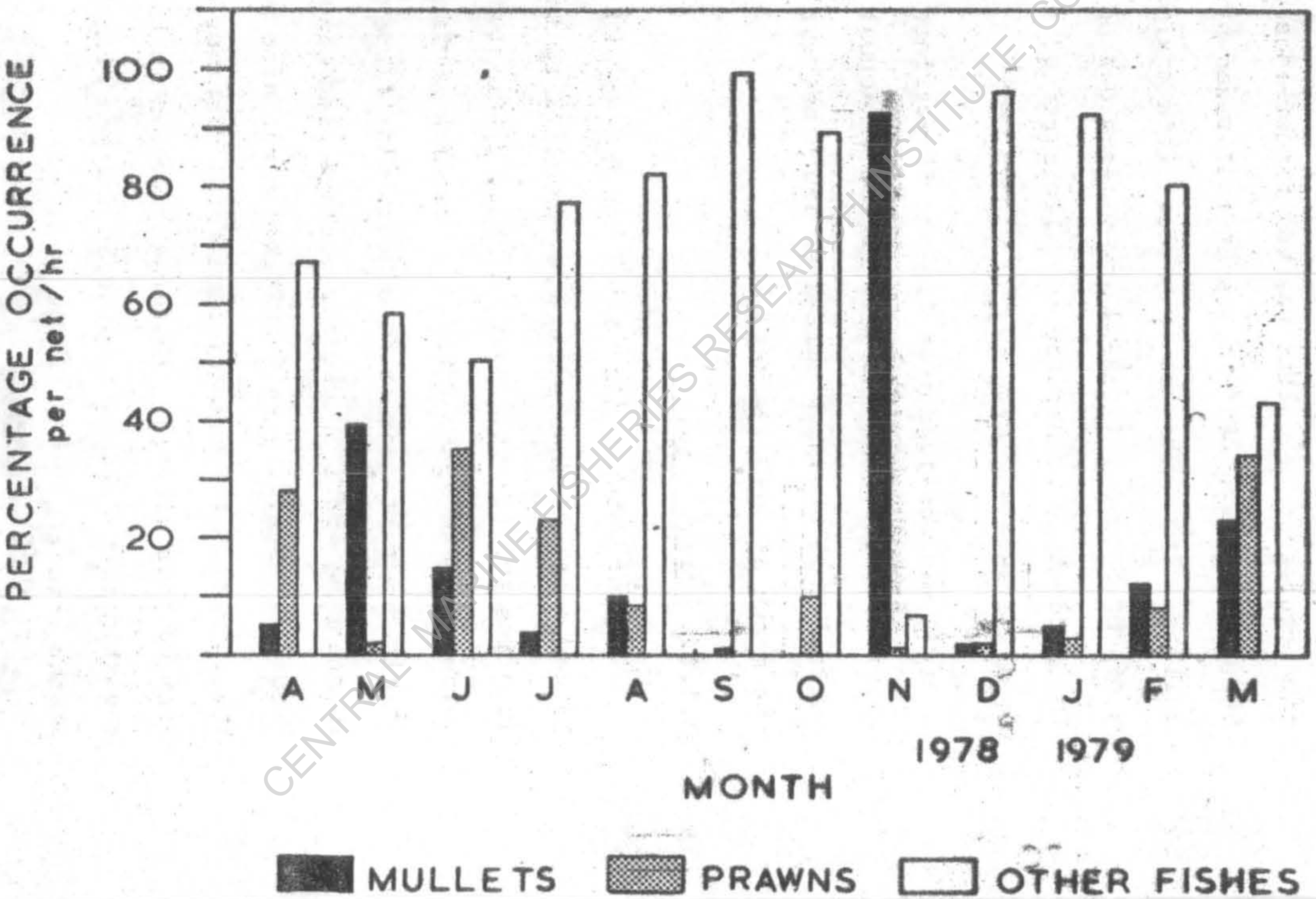
Table 5 Percentage abundance of mullet, prawn and other fish seed from Kovalam estuary (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	6	608	30	4.93	170	27.96	408	67.10
May	6	178	70	39.32	4	2.25	104	58.43
June	6	164	24	14.63	58	35.36	82	50.00
July	5	84	-	-	19	22.62	65	77.38
August	5	210	22	10.47	18	8.57	170	90.95
September	5	260	-	-	3	1.15	257	98.85
October	5	334	-	-	36	10.78	298	89.22
November	7	2155	1,980	91.88	17	0.79	158	7.33
December	8	2229	43	1.93	53	2.38	2,133	95.69
January	6	750	40	5.33	20	2.67	690	92.00
February	5	745	96	12.88	56	7.51	593	79.59
March	6	306	70	22.88	104	33.97	132	43.14

* Mean of two collections

SEASONAL VARIATION ON THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN KOVALAM ESTUARY DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 14



It may be seen that there is a seasonal variation in the occurrence of mullet fry and fingerlings . The period between July and October was characterized by the absence of mullets. The abundance of mullets were maximum during the month of November (91.88%) and minimum during December (1.93%). The percentage occurrence of mullets ranged from zero to 91.88% (Table 5 & Fig. 14).

It was observed that fry and fingerlings of prawns occurred throughout the year except in August. It may be noticed that the peak period of abundance was recorded during the month of June (35.36%).

3.1.1.6 Edayur estuary

Edayur estuary (12^{0} 35' N and 80^{0} 11' E) is situated 55 kms south of Madras and runs parallel to the sea coast. It joins the sea at Edayur village, 3 kms south of Mahabalipuram and 1 km east of Reactor Research Centre of Madras Atomic Power Project at Kalpakkam. The flood waters from the surrounding areas of Devanar village also mixes with the estuarine waters. The Buckingham canal also passes through the estuary. The estuary runs for a distance of about 5 kms from Devanar village. The area surveyed in the present investigation extends about 0.30 Sq. kms from the bar mouth of the estuary.

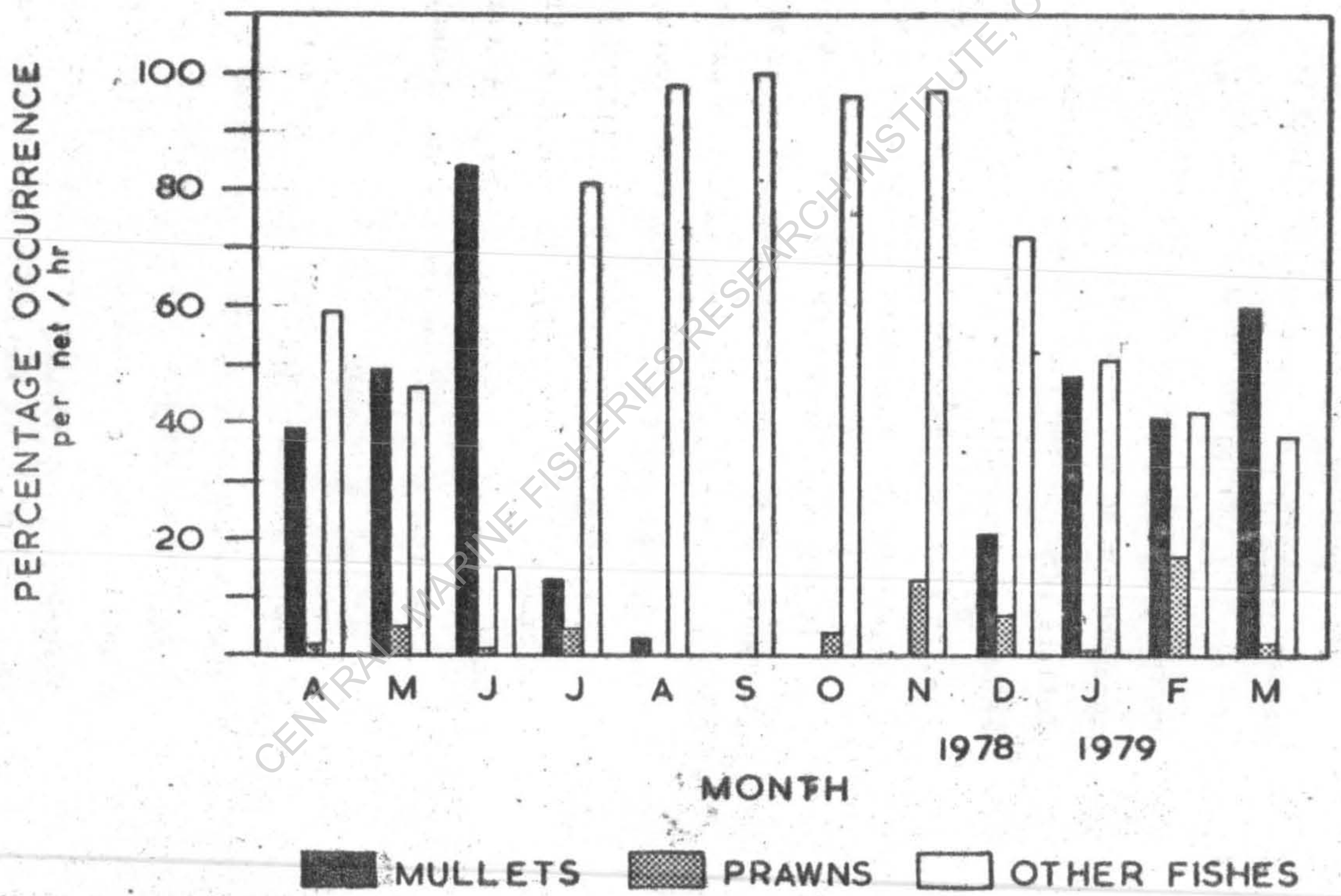
Table 6 Percentage abundance of mullet, prawn and other fish seed from Edayur estuary (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	5	554	218	39.35	10	1.80	326	58.84
May	5	136	67	49.26	7	5.15	62	45.59
June	8	2,211	1,872	84.67	5	0.23	334	15.10
July	5	221	29	13.12	12	5.43	180	81.45
August	5	192	5	2.60	-	-	187	97.39
September	5	36	-	-	-	-	36	100.00
October	6	166	-	-	6	3.61	160	96.38
November	5	190	-	-	24	12.63	166	87.37
December	5	518	108	20.85	38	7.33	372	71.81
January	7	1,106	528	47.74	7	0.63	571	51.63
February	5	240	101	42.08	41	17.08	98	40.83
March	5	621	372	59.90	14	2.25	235	37.84

* Mean of two collections

SEASONAL VARIATION IN THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN EDAYUR ESTUARY DURING THE PERIOD OF SURVEY - APRIL 1978 TO MARCH 1979

FIG. 15



The abundance of fry and fingerlings of mullets of this estuary appears to be seasonal in nature and the peak period was recorded during the month of June (84.67%). Among the percentage occurrence of mullets, minimum numbers were recorded during the month of August, the value being 2.60%. Mullets were not recorded during September-November when the bar mouth was closed. It may be seen from Table 6 & Fig. 15 that the abundance curve of mullets bears an inverse relationship with the abundance of prawns and other fishes.

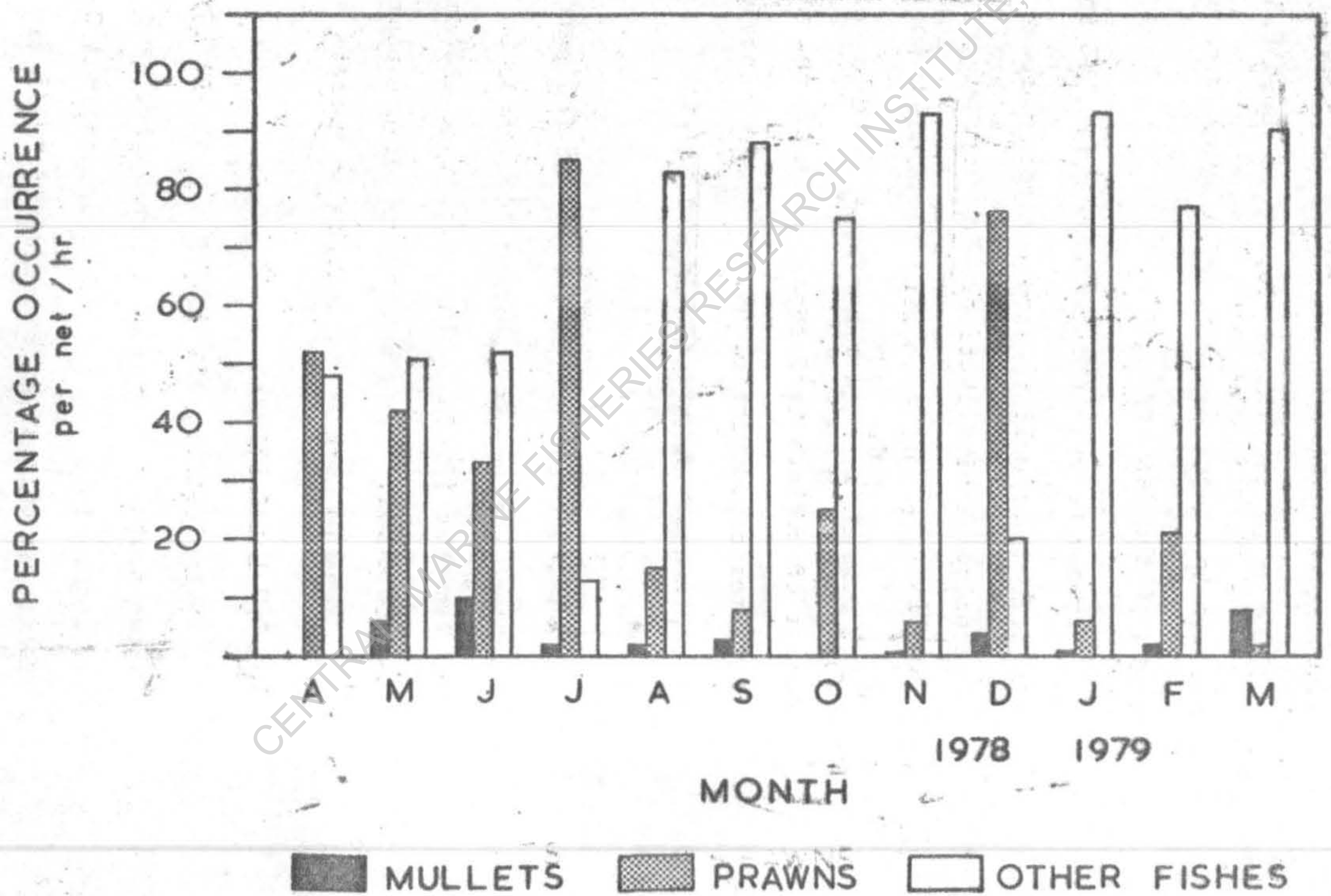
It may be indicated from Table 6 & Fig. 15 that the abundance of fry and fingerlings of prawns are relatively poorer when compared to other estuaries except Cooum where there was nil occurrence. Prawns were recorded in maximum number during the month of February (17.08%) and in minimal number during June (0.23%). Fry and fingerlings of prawns were not recorded during the months of August and September when the bar mouth of the estuary was closed.

3.1.1.7 Sadras estuary

Sadras estuary (12° 31' N and 80° 10' E) popularly known as Pudupattinam estuary is located 65 kms south of Madras and enters into the sea at Sadras near Kalpakkam township. The over flow water of an irrigation tank flows through different villages of Chingleput district and enters this estuary. The Buckingham canal which runs parallel to the

SEASONAL VARIATION IN THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN SADRAS ESTUARY DURING THE PERIOD OF SURVEY ARRIL 1978 TO MARCH 1979

FIG. 16



sea coast passes through the estuary. Major part of the estuary runs perpendicular to the sea coast. The area covered under the present survey is about 0.30 sq. kms between the junction point of Buckingham canal and the bar mouth of the estuary.

It may be seen from Table 7 & Fig. 16 that the fry and fingerlings of mullets were recorded throughout the year with discontinuous distribution. The percentage abundance was poor and it ranged from zero to 10.53%. During the month of June, relatively higher number of mullets were caught. Less number of mullets were recorded during the month of January, the percentage being 0.40%. No definite relationship between the abundance of mullets and prawns/other fishes may be observed.

Prawns occur almost throughout the year and their peak abundance was recorded during the months of July (84.35%) and December (6.40%). The percentage abundance varied from 6.40 to 84.35. The abundance of prawns bear an inverse relationship with the abundance of mullets and other fishes.

3.1.1.8 <u>Palar estuary</u>

Palar estuary (12° 28' N and 80° 9' E) is located 70 kms south of Madras runs perpendicular to the sea coast and enters into the sea near Pudupattinam Colony at Kadalur Village in Chingleput district of Tamil Nadu. The Cheyyar

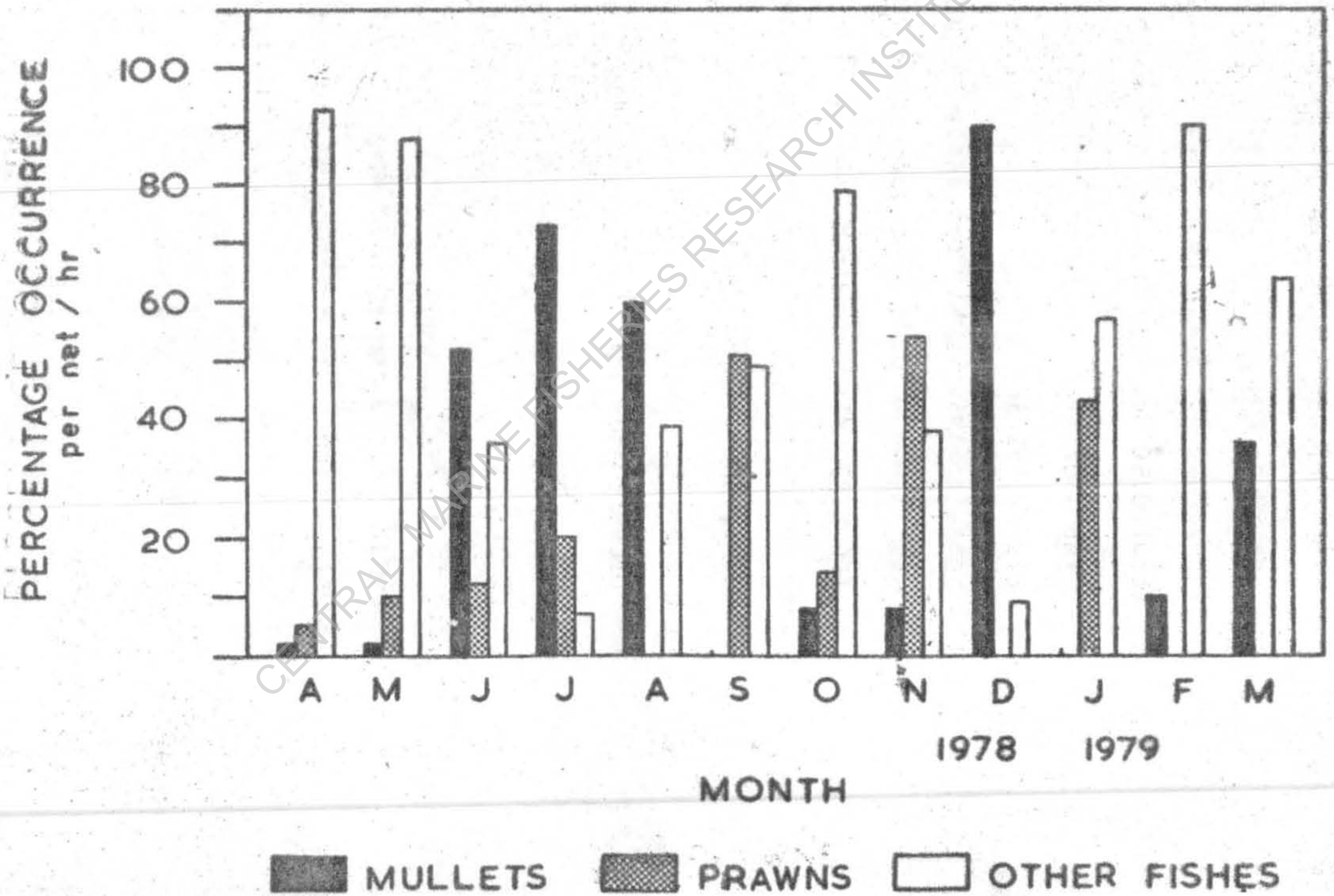
Table 8 Percentage abundance of mullet, prawn and other fish seed from Palar estuary (April 1978 to March 1979) *

Month	Number of drag	Estimated total number of seed per net/hr	Estimated number and percentage of seed per net/hr					
			Mullets	%	Prawns	%	other fishes	%
April	7	977	19	1.94	44	4.50	914	93.55
May	5	249	5	2.00	24	9.64	220	88.35
June	5	502	264	52.58	58	11.55	180	35.86
July	5	991	720	72.65	199	20.08	72	7.26
August	6	76	46	60.52	-	-	30	39.47
September	7	59	-	-	30	50.85	29	49.15
October	5	386	26	6.73	55	14.25	305	79.01
November	5	1,274	98	7.69	691	54.24	485	38.07
December	8	85,791	77,670	90.53	3	0.01	8,118	9,46
January	7	2,325	12	0.52	991	42.62	1,322	56.86
February	5	773	77	9.96	-	-	696	90.03
March	5	372	134	36.02	-	-	238	63.98

* Mean of two collections

SEASONAL VARIATION IN THE PERCENTAGE COMPOSITION OF MULLET PRAWN AND OTHER FISH SEED IN PALAR ESTUARY DURING THE PERIOD OF SURVEY - APRIL 1978 TO MARCH 1979

FIG. 17



river which runs east of Kancheepuram joins this estuary and flows through a distance of about 20 kms and then joins the sea. The Buckingham canal runs parallel to this estuary at Pudupattinam. The area covered under the present study is about 0.50 Sq. kms from the bar mouth of the estuary.

The abundance of fry and fingerlings of mullets appears to be seasonal in nature. Though mullets occur throughout the year, maximum number was recorded during the month of December (90.53%). Minimum percentage occurrence of mullets was recorded during January (0.52). The abundance of mullets bears an inverse relationship with prawns and other fishes. Moreover, the predominance of mullets over prawns and other fishes in this estuary resembles other estuaries surveyed in the present study (Table 8 & Fig. 17).

The abundance of fry and fingerlings of prawns showed seasonal variation. The percentage occurrence ranged from zero to 54.24. Maximum number of prawns was recorded during November (54.24) and minimum during April (4.50%). Prawn fry and fingerlings were not represented in the catches during the months of August, December, February and March.

TABLE 9 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET <u>LIZA MACROLEPIS</u> (SMITH) AND PRAWN <u>PENAEUS INDICUS</u> MILNE-EDWARDS IN PULICAT LAKE (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	33.33	-	-	-	50.00	-	-	4.37	-	-	38.46	-	75.00	-	-	-	-	-	-	-	12.50	-	-	-
15-19	33.33	-	3.84	-	-	11.76	-	34.78	40.00	37.50	7.69	6.75	12.50	72.72	-	11.15	-	-	18.60	-	12.50	-	-	-
20-24	-	3.12	3.84	3.44	-	29.44	25.00	26.08	20.00	31.22	7.69	12.16	-	18.19	-	19.44	-	30.30	11.65	6.66	-	9.30	-	4.87
25-29	-	6.25	-	10.34	25.00	17.64	50.00	26.08	40.00	12.50	15.38	6.75	12.50	9.09	-	25.00	-	30.30	51.16	16.66	30.00	11.67	-	6.09
30-34	16.66	21.87	11.53	27.58	25.00	17.64	25.00	8.69	-	18.75	30.76	32.43	-	-	-	16.66	-	21.22	16.27	16.66	40.00	27.90	-	36.58
35-39	16.67	21.87	15.38	10.34	-	5.88	-	-	-	-	-	18.91	-	-	-	8.33	-	10.00	2.32	13.38	5.00	9.30	-	18.32
40-44	-	12.50	26.98	3.44	-	-	-	-	-	-	-	13.51	-	-	-	5.55	-	3.03	-	16.66	-	9.30	14.28	12.19
45-49	-	15.65	11.53	10.34	-	-	-	-	-	-	-	6.75	-	-	-	5.55	-	-	-	3.33	-	4.65	28.56	10.97
50-54	-	9.37	7.69	6.89	-	11.76	-	-	-	-	-	1.35	-	-	-	5.55	-	-	-	-	-	6.97	-	2.43
55-59	-	3.12	3.84	13.86	-	5.88	-	-	-	-	-	1.35	-	-	-	-	-	3.03	-	3.33	-	2.32	-	2.43
60-64	-	6.25	3.84	3.44	-	-	-	-	-	-	-	-	-	-	-	-	-	3.03	-	10.00	-	6.97	-	1.23
65-69	-	-	7.69	3.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.66	-	4.65	28.56	1.23
70-74	-	-	-	6.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.97	14.28	1.23
75-79	-	-	3.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.33	-	-	14.28	2.43
80-84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.33	-	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG.18 A - F - SIZE GROUP DISTRIBUTION OF MULLET, & PRAWN IN PULICATE LAKE DURING THE PERIOD OF SURVEY - APRIL 1978 TO MARCH 1979

FIG. 18 - B

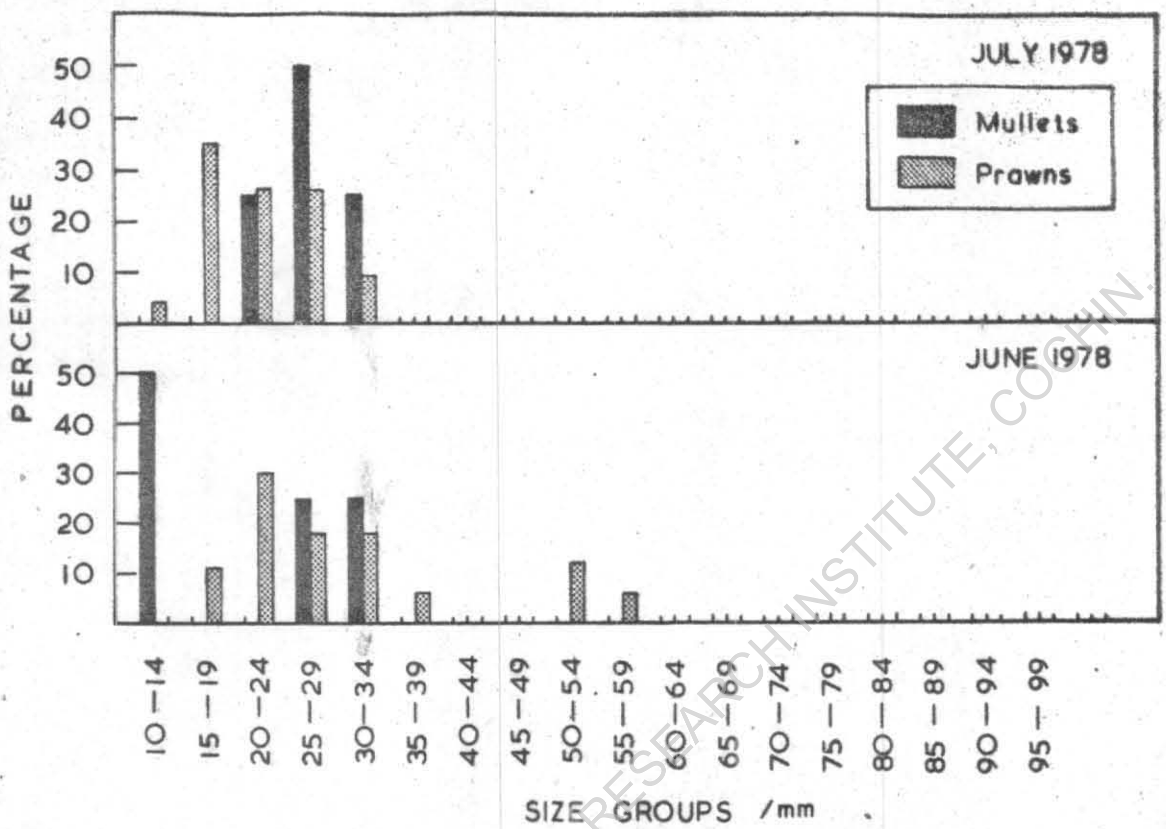


FIG. 18 - A

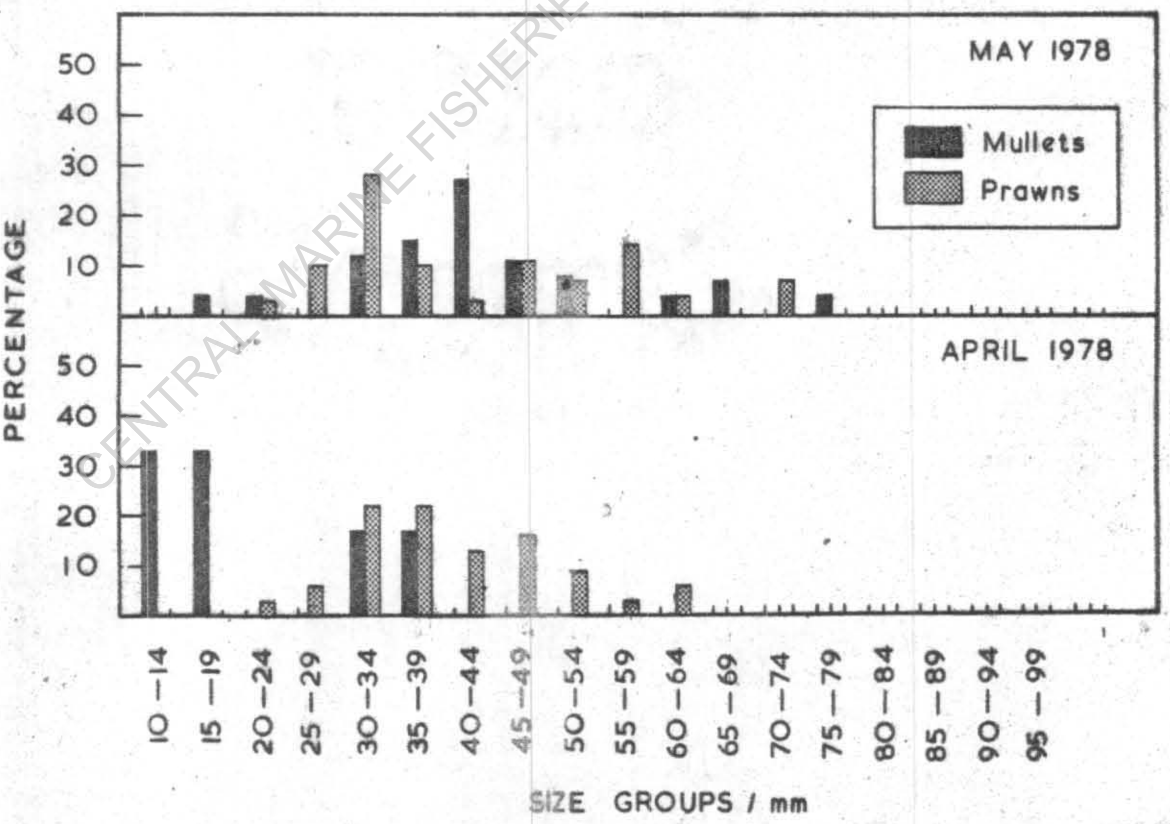


FIG. 18 - D

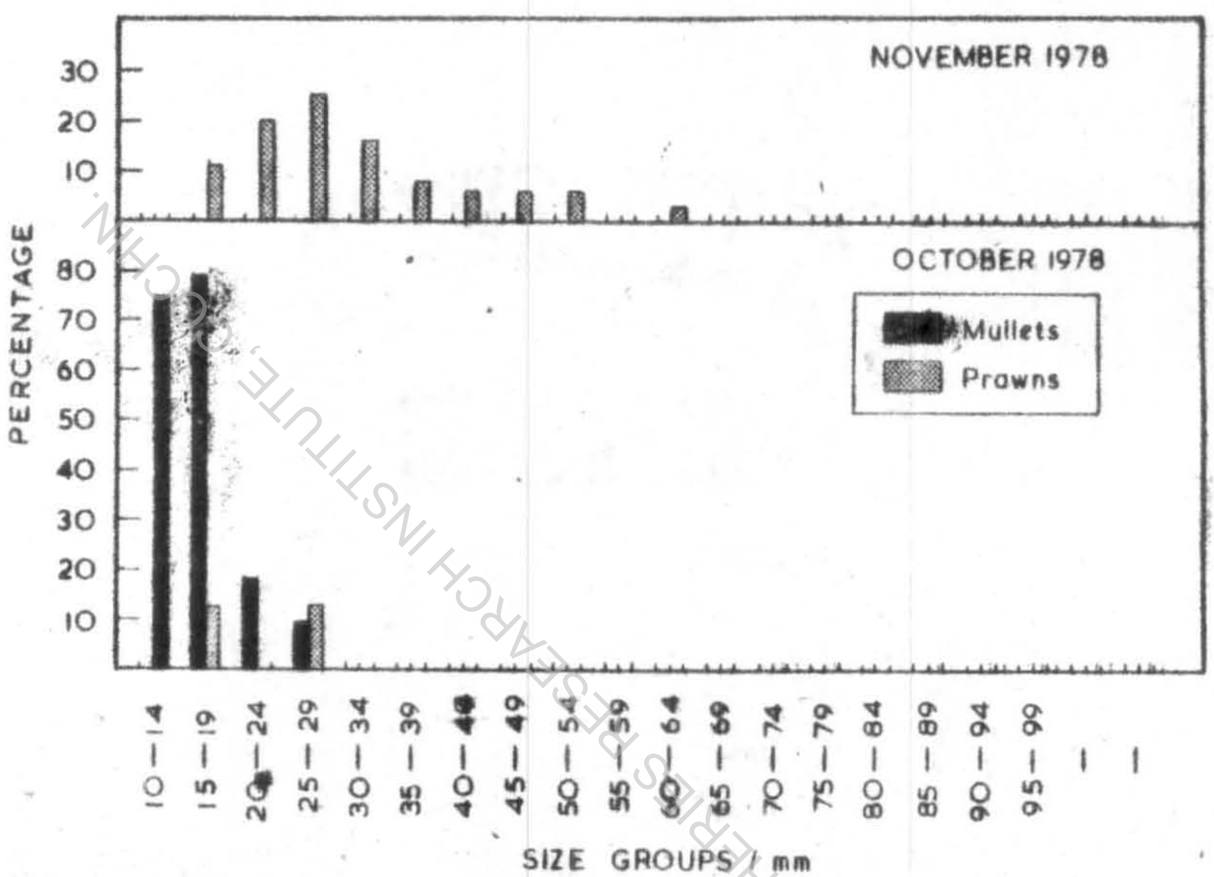


FIG. 18 - C

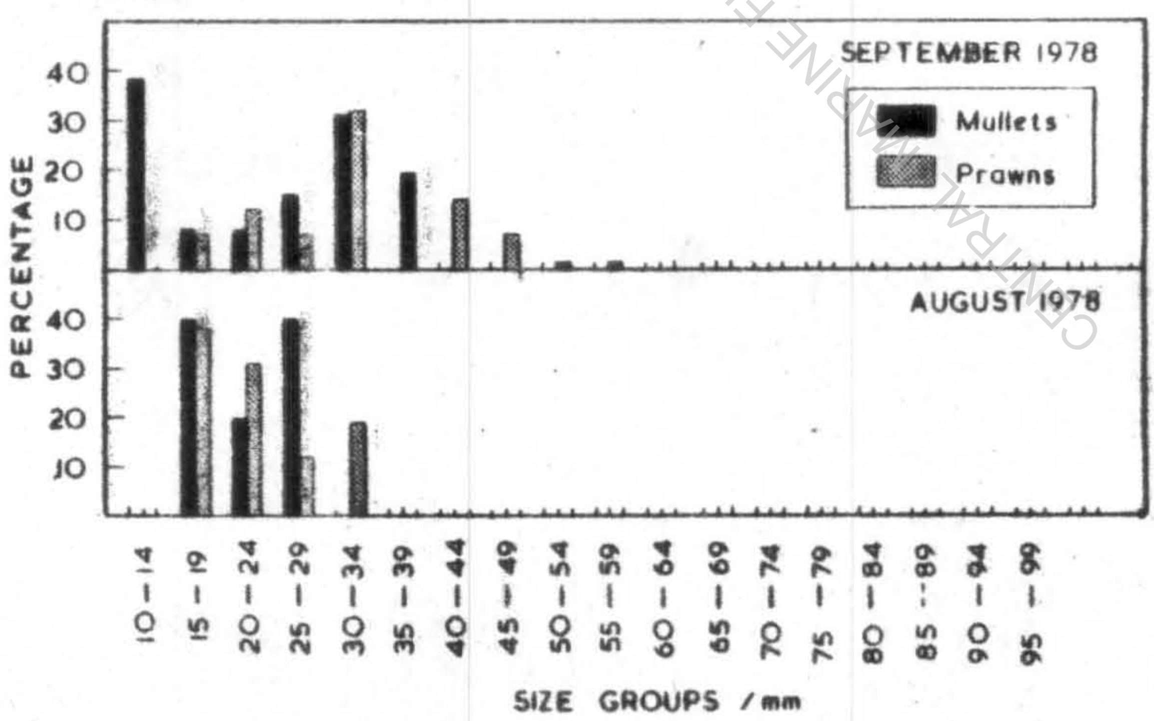


FIG. 18 - F

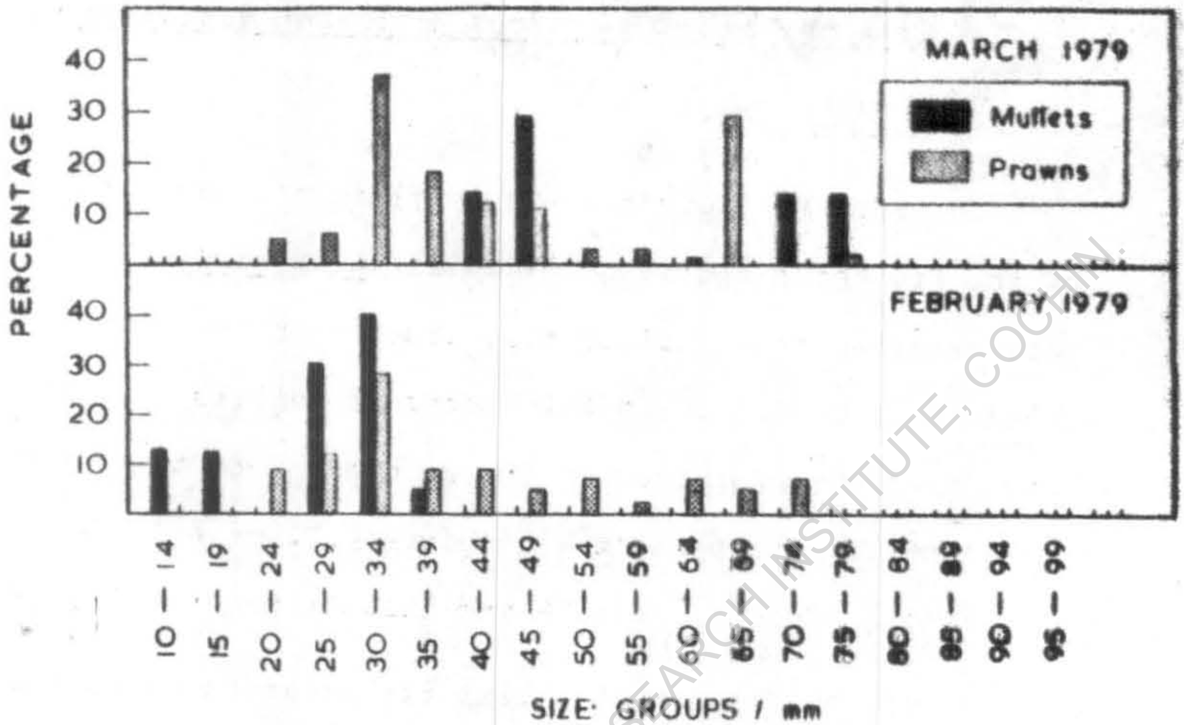
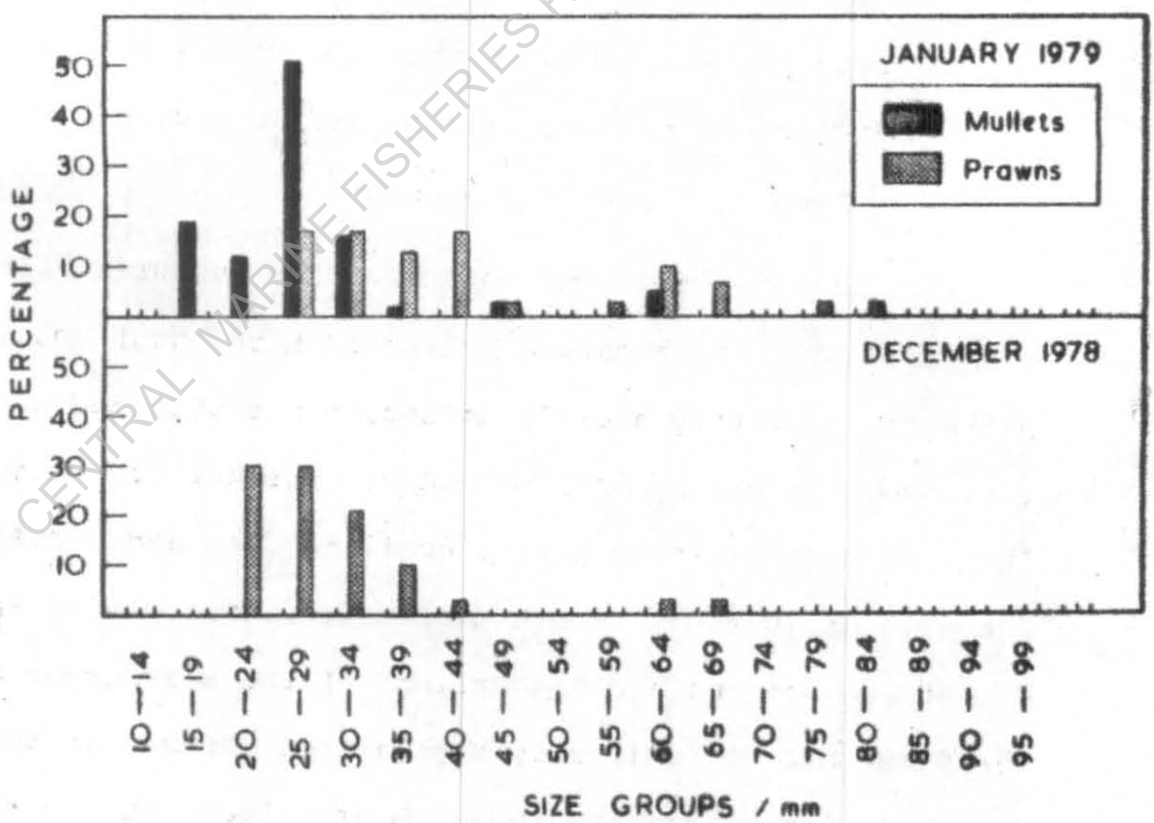


FIG. 18 - E



3.1.2 Distribution pattern of various size groups of mullet and prawn seed from different estuaries

3.1.2.1 Pulicat lake

In order to study the length frequency distribution of the fry and fingerlings of mullet *L. macrolepis*, they were assorted into various size groups with an length interval of 5 mm. The total number of mullets in each size group was expressed as the percentage of the total number of mullets present in a given collection. The results are given in Table 9 and illustrated in Fig. 18 A-F.

It may be noted that mullet fry occurred throughout the year except in November and December. An analysis of the size frequency distribution pattern indicates that in a given month one or two size groups may be represented well, while the rest were poorly represented.

It is interesting to note that fry measuring less than 35 mm in length may be collected throughout the year, while fry measuring over 35 mm showed a restricted distribution during March, April and May. Further fry measuring 10-14 mm were dominant during April to June and September. The size group 15-19 mm was well represented during April, August and October and fingerlings of the size group above 45-49 mm were not uniformly represented throughout the survey period. From the above observations, it may be

TABLE 10 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET LIZA MACROLEPIS (SMITH) AND PRAWN PENAEUS INDICUS MILNE-EDWARDS IN ENNORE ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	59.52	-	-	-	26.12	-	50.00	40.00	60.00	-	62.26	-	-	-	9.19	-	5.00	5.00	9.52	-	12.50	-	28.00	-
15-19	35.72	-	-	-	58.69	50.00	50.00	-	20.00	33.33	37.74	-	42.85	-	24.17	18.75	25.00	62.50	14.40	-	12,50	-	67.00	-
20-24	-	42.30	-	-	-	16.66	-	-	20.00	50.00	-	-	-	67.50	47.12	46.87	38.75	22.50	50.00	20.00	-	9.30	5.00	-
25-29	2.38	41.02	-	-	-	-	-	60.00	-	-	-	-	7.14	7.50	3.44	3.15	1.25	-	23.80	-	30.00	11.67	-	-
30-34	2.38	11.53	-	33.33	4.34	33.37	-	-	-	-	-	-	35.71	-	12.64	6.25	1.25	5.00	2.38	60.00	40.00	27.90	-	33.34
35-39	-	5.12	-	24.99	-	-	-	-	16.67	-	-	-	14.28	-	-	-	-	5.00	-	-	5.00	9.30	-	8.33
40-44	-	-	-	24.90	-	-	-	-	-	-	-	-	-	-	3.44	-	5.00	-	-	20.00	-	9.30	-	25.00
45-49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.50	11.25	-	-	-	-	4.65	-	8.33
50-54	-	-	-	-	-	-	-	-	-	-	-	-	-	5.00	-	3.12	10.00	-	-	-	-	6.97	-	-
55-59	-	-	-	8.33	4.34	-	-	-	-	-	-	-	-	5.00	-	3.12	-	-	-	-	-	2.32	-	25.00
60-64	-	-	-	-	2.17	-	-	-	-	-	-	50.00	-	2.50	-	3.12	2.50	-	-	-	-	6.97	-	-
65-69	-	-	-	8.33	2.17	-	-	-	-	-	-	25.00	-	5.00	-	3.12	-	-	-	-	-	4.65	-	-
70-74	-	-	-	-	2.17	-	-	-	-	-	-	25.00	-	-	-	-	-	-	-	-	-	6.97	-	-
75-79	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	-	-	-	-	-	-	-	-	-	-
80-84	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	-	-	-	-	-	-	-	-	-	-
85-89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90-94	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	-	-	-	-	-	-	-	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG. 19 - F

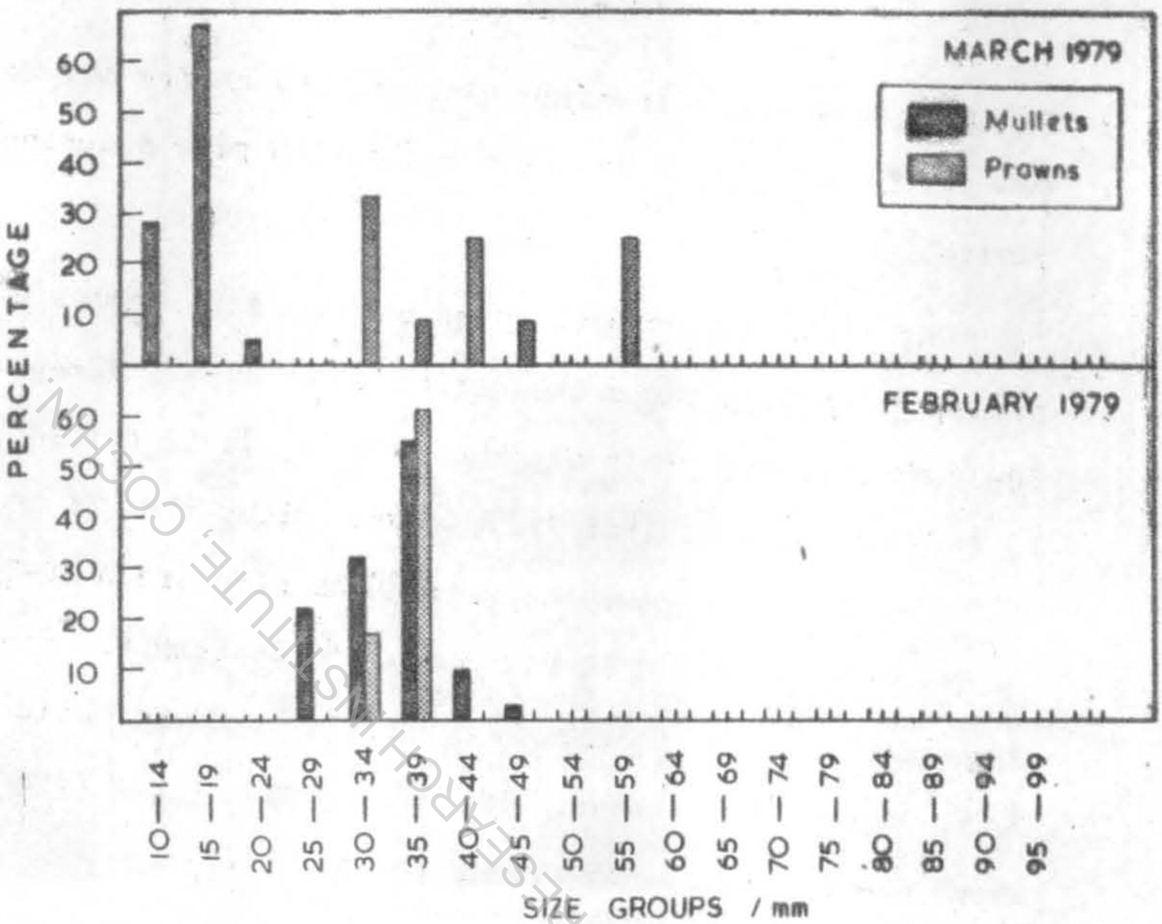


FIG.- 19 - E

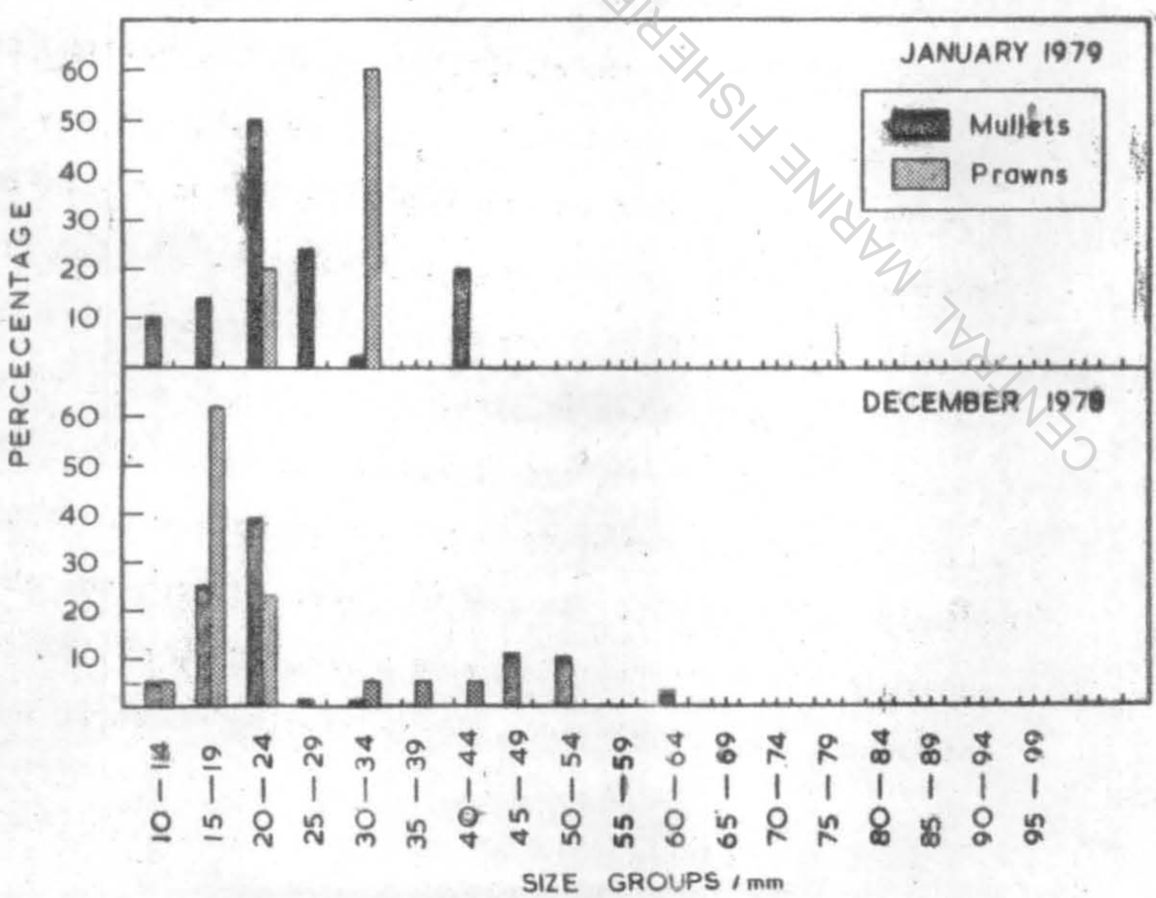


FIG. 19 - D

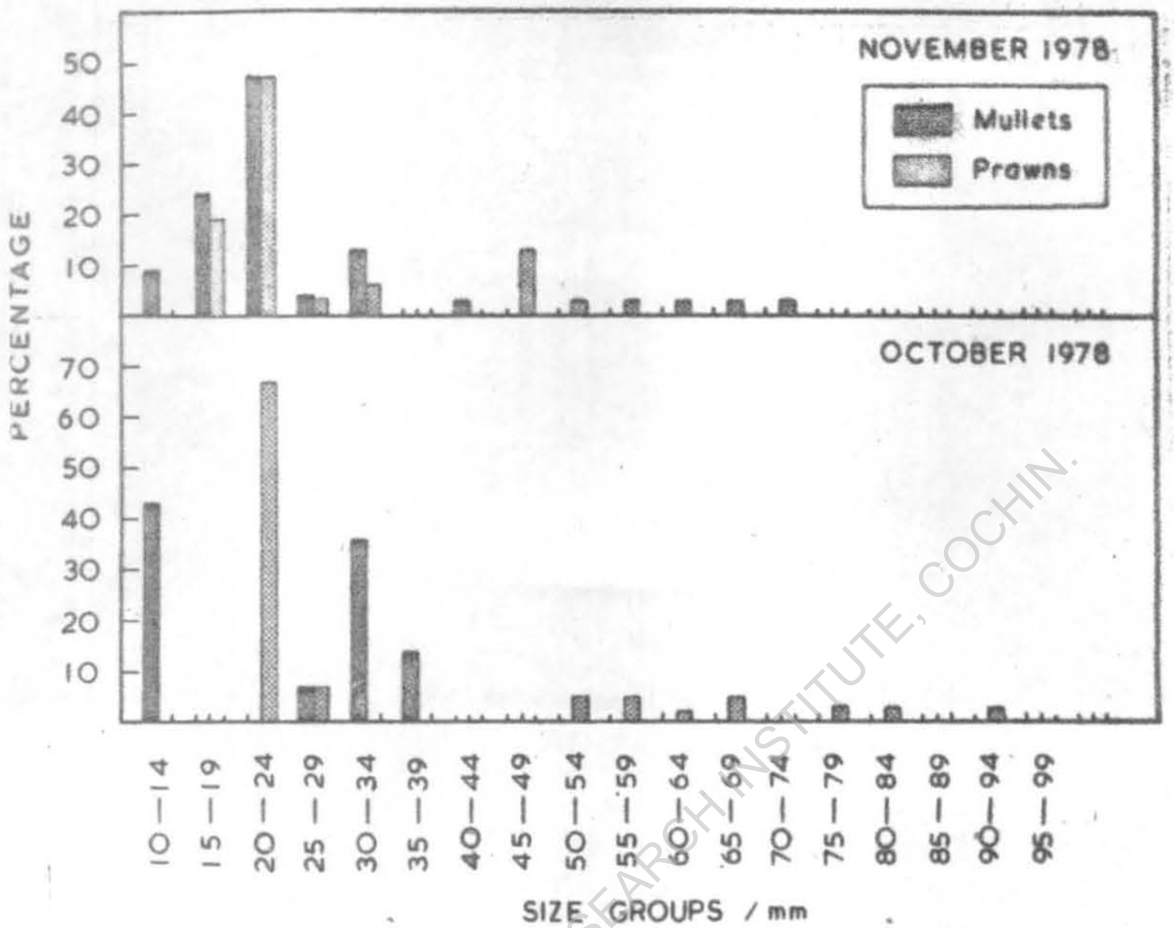


FIG. 19 - C

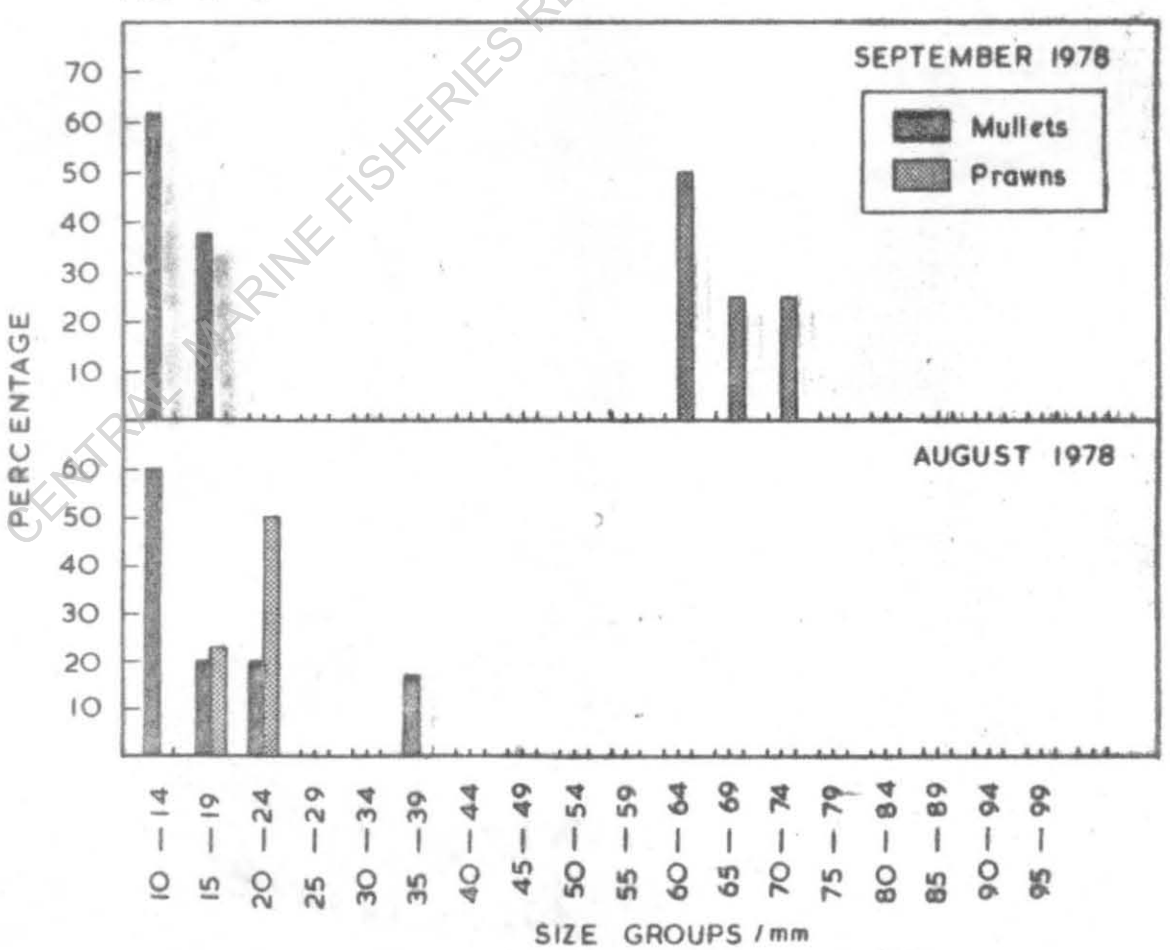


FIG. 19 - A - F SIZE GROUP DISTRIBUTION OF MULLET AND PRAWN IN ENNORE ESTUARY DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 19 - B

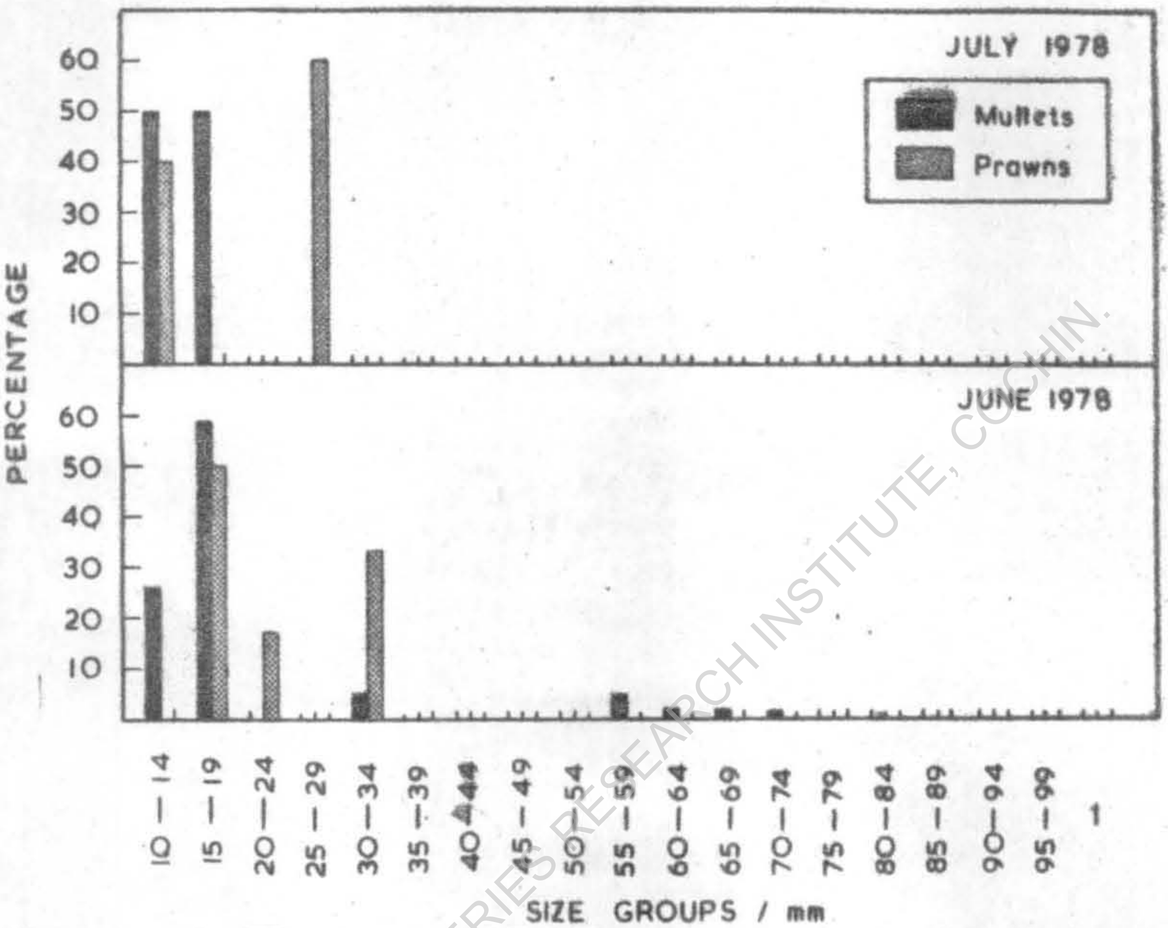
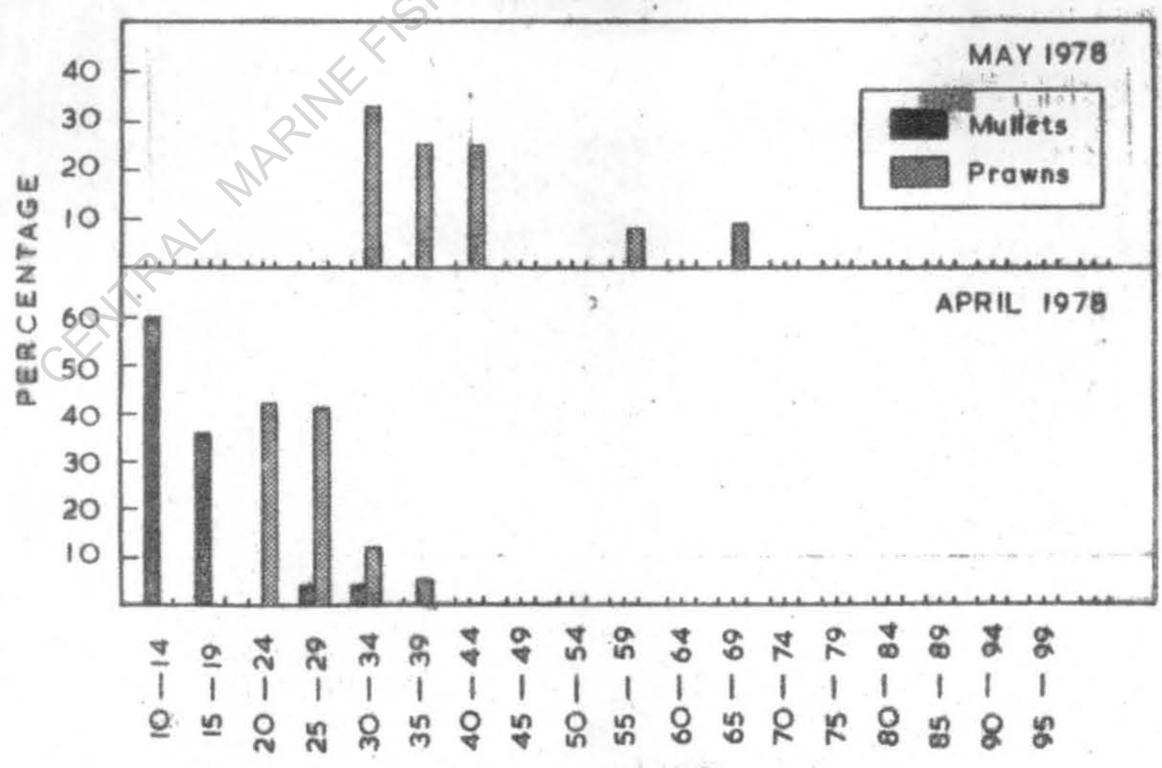


FIG. 19 - A



inferred that the year round availability of fry may be due to its continuous breeding cycle with peak spawning periods.

The distribution pattern of various size groups of prawn, P. *indicus* shows the dominance of 15-19, 20-24 and 30-34 mm size groups in all the months. It is evident from Table 9 and Fig. 18 that fry measuring less than 35 mm may be collected throughout the year. The size group 30-34 mm was dominant during January to May and September. Fingerlings measuring above 35 mm showed a restricted distribution during July, August and October. The size group of the fingerlings above 85-89 mm were not caught in the net.

3.1.2.2 Ennore estuary

An analysis of the distribution of the various size groups are given in Table 10 & Fig. 19 A-F. It may be noted that in a given month one or two size groups may be dominant. Other size groups were poorly represented. Mullet fry of the size groups 10-14 & 15-19 mm were dominant in all the months. Fry of the size group 20-24 mm was well represented during January, March and November and fingerlings of the size group above 40-44 mm were not uniformly represented throughout the year. It may be inferred from the above observations that fry measuring below 20 mm may be collected throughout the year, while fry measuring above 20 mm show a

TABLE 11 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET LIZA MACROLEPIS (SMITH) AND PRAWN PENAEUS INDICUS MILNE-EDWARDS IN COOUM ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	33.33	-	48.00	-	26.33	-	-	-	-	-	-	-	-	-	-	-	7.69	-	7.84	-	27.74	-	38.88	-
15-19	33.33	-	50.00	-	-	-	-	-	-	-	-	-	-	-	52.0	-	23.07	-	31.37	-	30.55	-	27.77	-
20-24	8.35	-	-	-	-	-	-	-	-	-	-	-	-	-	28.00	-	46.17	-	39.23	-	36.13	-	-	-
25-29	16.66	-	-	-	-	-	-	-	-	-	-	-	-	-	5.00	-	-	-	19.60	-	5.55	-	33.35	-
30-34	-	-	2.00	-	5.26	-	-	-	-	-	-	-	-	-	-	-	15.38	-	1.96	-	-	-	-	-
35-39	8.33	-	-	-	52.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40-44	-	-	-	-	10.52	-	-	-	-	-	-	-	-	-	-	-	7.69	-	-	-	-	-	-	-
45-49	-	-	-	-	5.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG. 20. A - D SIZE GROUP DISTRIBUTION OF MULLET AND PRAWN IN COOUM ESTUARY DURING THE PERIOD OF SURVEY APRIL - 1978 TO MARCH - 1979

FIG. 20 - B

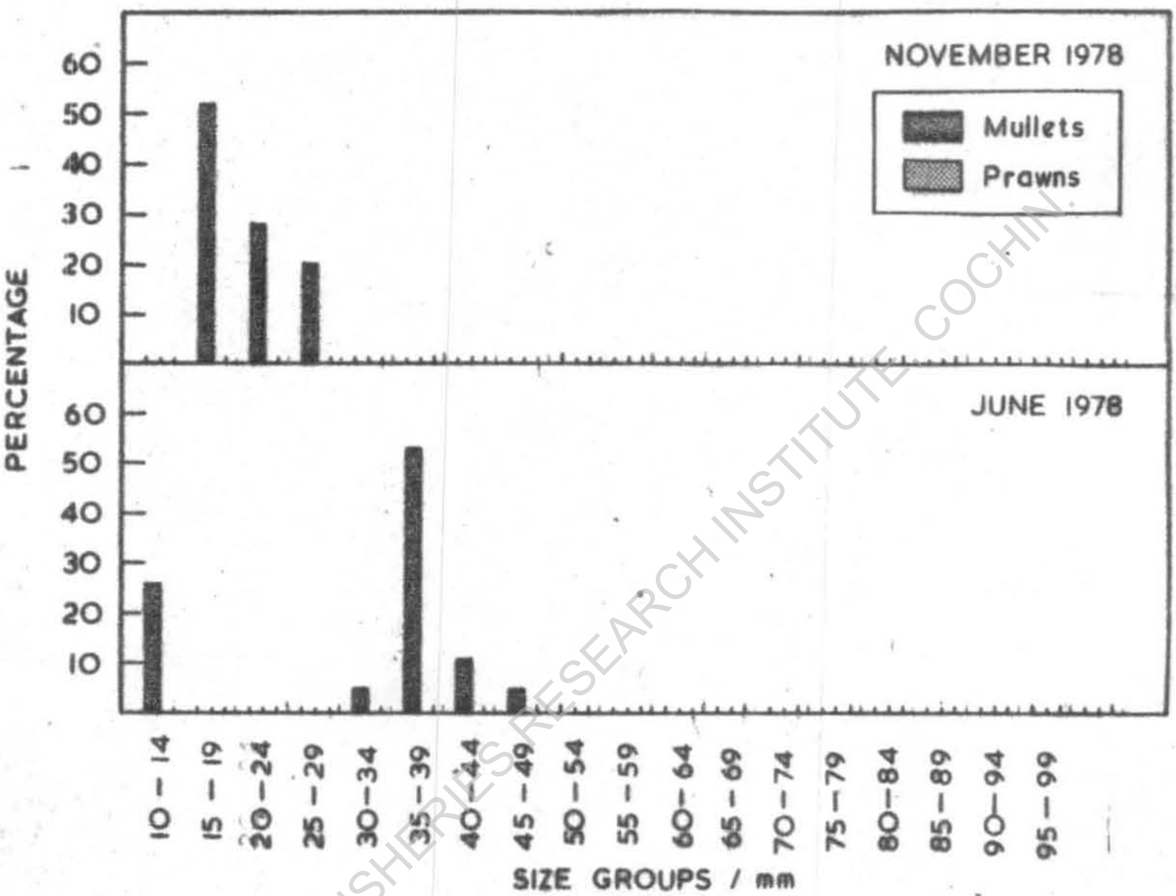
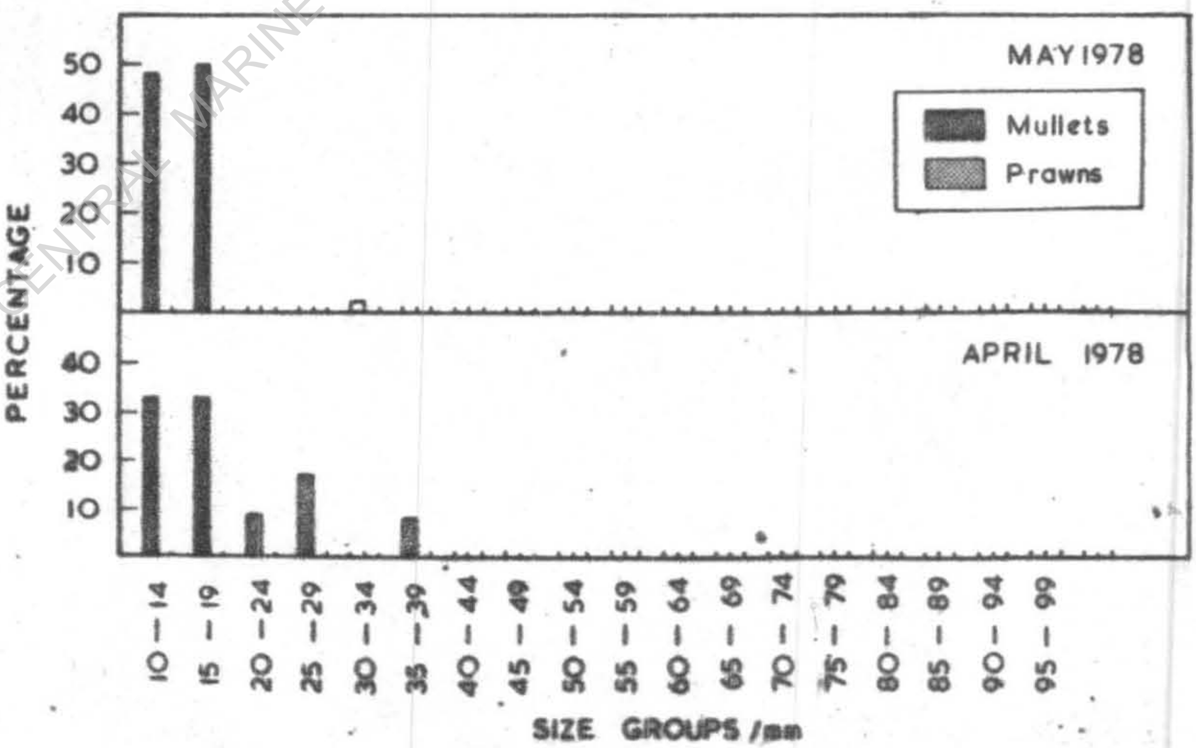


FIG. 20 - A



JULY TO OCTOBER 1978 - nil

FIG. 20 -D

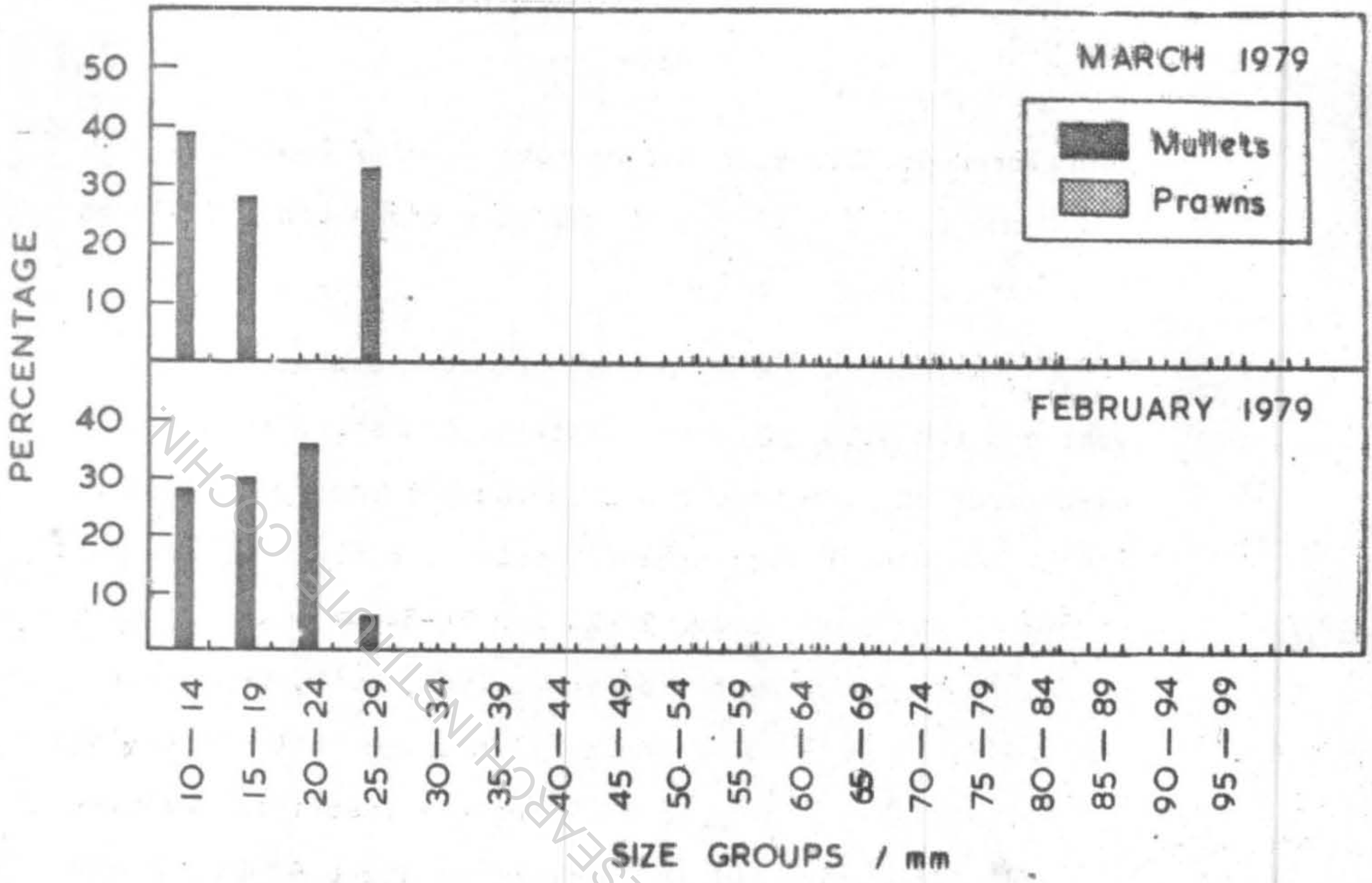
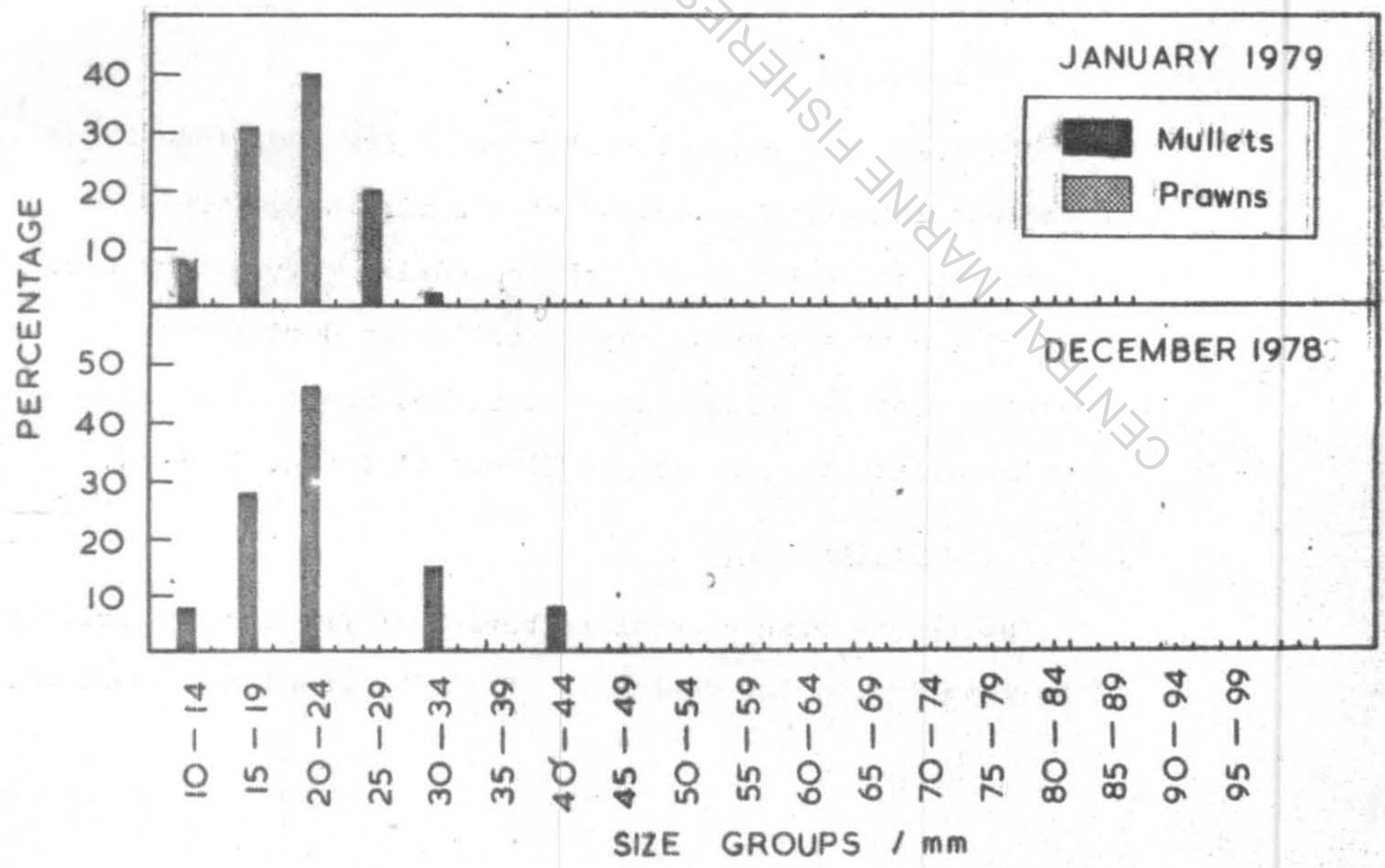


FIG. 20 -C



restricted distribution during April, July, September and October. Fingerlings of the size group above 70-74 mm were very poorly represented.

It may be seen that prawns occurred throughout the year and the size frequency distribution shows that the size group 10-14 mm may occur throughout the year but may not be a dominant size group. Table 10 & Fig. 19 show that prawns of the size groups 20-24 and 30-34 mm were dominant in all the months except February, June, July, September and December. The above observation shows that fingerlings of the size group above 35-39 mm have a restricted distribution. Fingerlings of the size group above 90-94 mm were scantly represented.

3.1.2.3 Cooum estuary

The size frequency distribution of fry and fingerlings of mullets shows the dominance of the size group 10-14 mm only during the months of March and April. Fry of the size groups 15-19 mm and above may be collected during the remaining months. Fingerlings measuring above 49 mm were not represented in the catches (Table 11 & Fig. 20 A-D).

3.1.2.4 Adyar estuary

The length frequency distribution of fry and fingerlings of mullets showed the dominance of 15-19, 20-24 and 30-34 mm,

TABLE 12 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET LIZA MACROLEPIS (SMITH) AND PRAWN <u>PENAEUS INDICUS</u> MILNE-EDWARDS IN ADYAR ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	6.83	-	0.50	-	-	6.66	-	6.66	-	-	-	-	39.10	-	-	-	-	-	1.76	-	13.87	75.00	6.53	-
15-19	11.96	16.66	59.00	11.56	-	10.00	-	73.35	-	1.27	-	0.69	48.07	10.00	9.33	-	5.88	60.00	36.28	-	59.23	25.00	47.54	-
20-24	3.45	8.33	30.00	25.00	-	10.00	14.28	13.33	-	17.19	-	13.19	7.05	30.00	64.00	-	30.88	13.35	45.13	-	10.76	-	1.67	6.25
25-29	43.58	16.66	6.50	27.88	33.33	6.66	28.59	6.66	-	33.12	-	47.22	0.34	16.67	21.34	-	58.82	-	10.61	16.66	8.46	-	2.45	31.25
30-34	27.35	33.35	1.00	20.19	33.33	10.00	-	-	-	30.57	-	33.33	4.80	20.00	5.33	8.33	1.48	13.33	1.76	-	6.15	-	14.75	21.87
35-39	5.12	25.00	-	10.57	-	36.66	-	-	-	14.01	-	4.16	10.64	10.00	-	-	2.94	6.66	5.80	22.22	1.53	-	19.67	18.75
40-44	1.70	-	-	0.96	16.77	13.36	-	-	-	3.84	-	1.41	-	10.00	-	8.33	-	-	-	27.77	-	-	1.63	6.25
45-49	-	-	1.50	1.92	-	6.66	-	-	-	-	-	-	-	-	-	50.00	-	-	-	33.33	-	-	2.45	6.25
50-54	-	-	0.50	0.96	16.77	-	14.28	-	-	-	-	-	-	3.33	-	25.00	-	6.66	-	-	-	-	2.45	3.13
55-59	-	-	-	0.96	-	-	28.57	-	-	-	-	-	-	-	-	8.34	-	-	-	-	-	-	0.84	-
60-64	-	-	-	-	-	-	14.28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
65-69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70-74	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG. 21 A-F SIZE GROUP DISTRIBUTION OF MULLET AND PRAWN IN ADYAR ESTUARY DURING THE PERIOD OF SURVEY – APRIL 1978 TO MARCH 1979

FIG. 21 - B

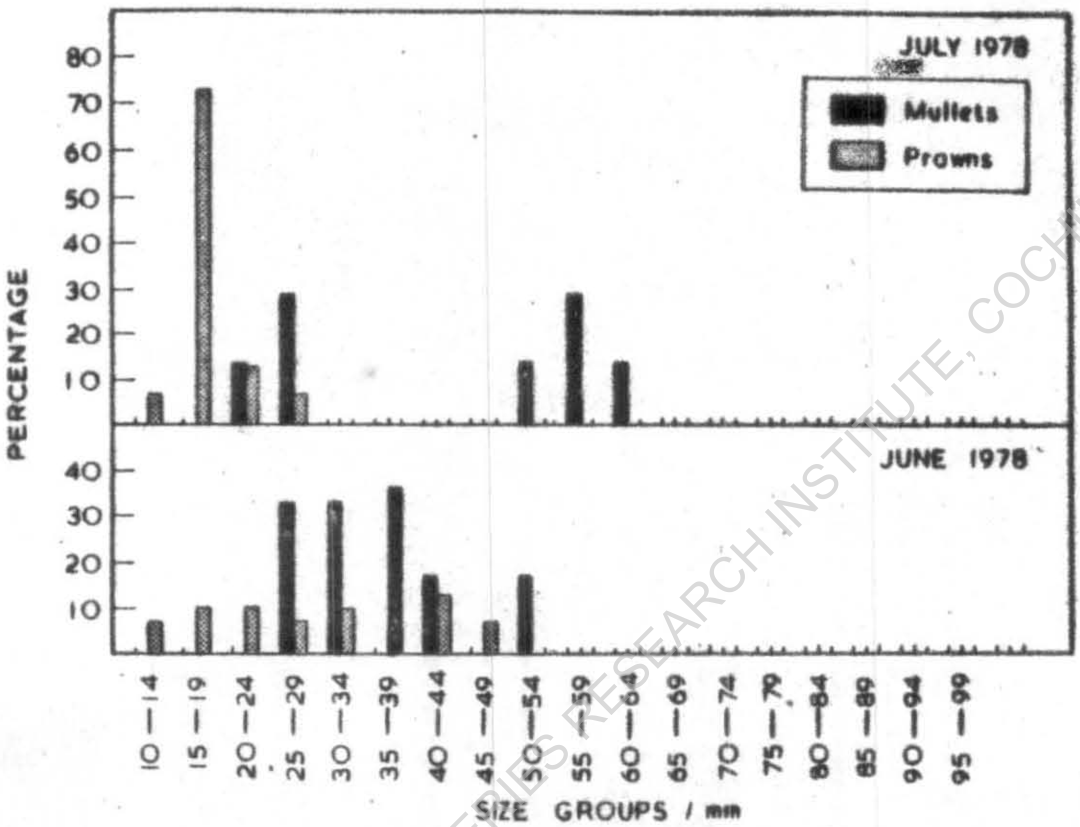


FIG. 21 - A

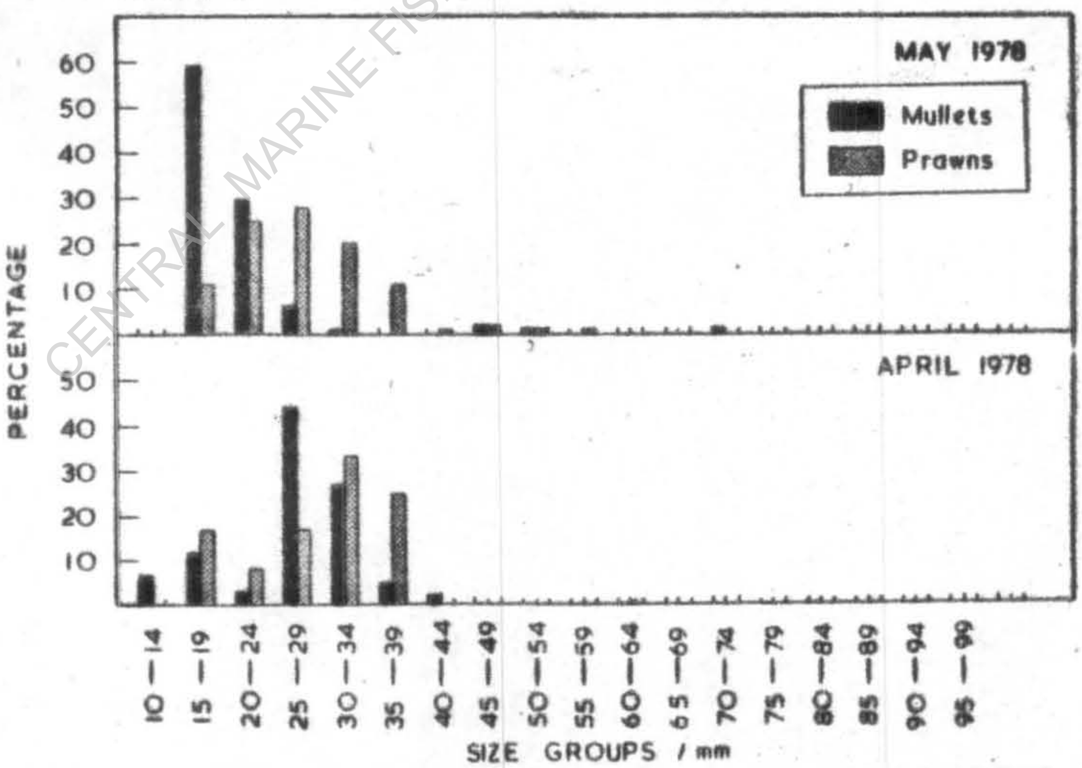


FIG. 21 - D

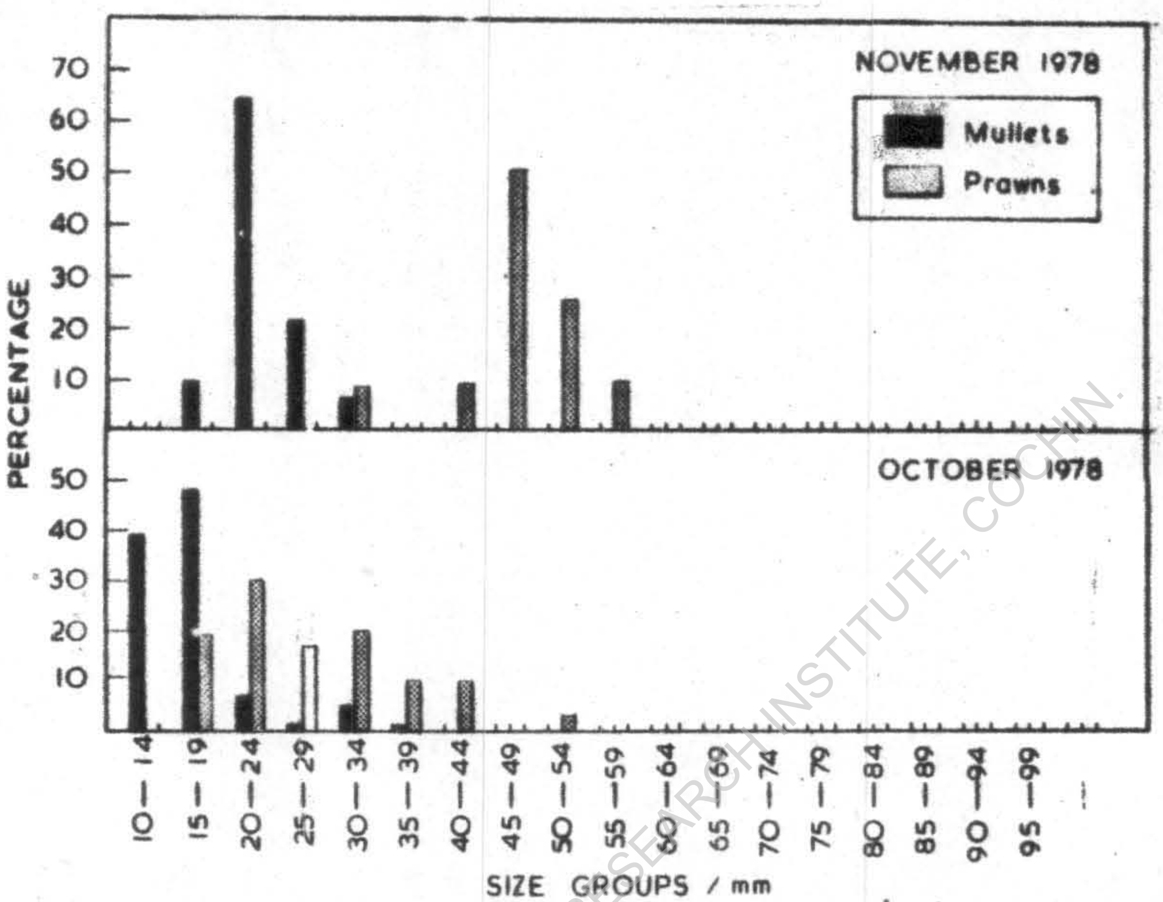


FIG. 21 - C

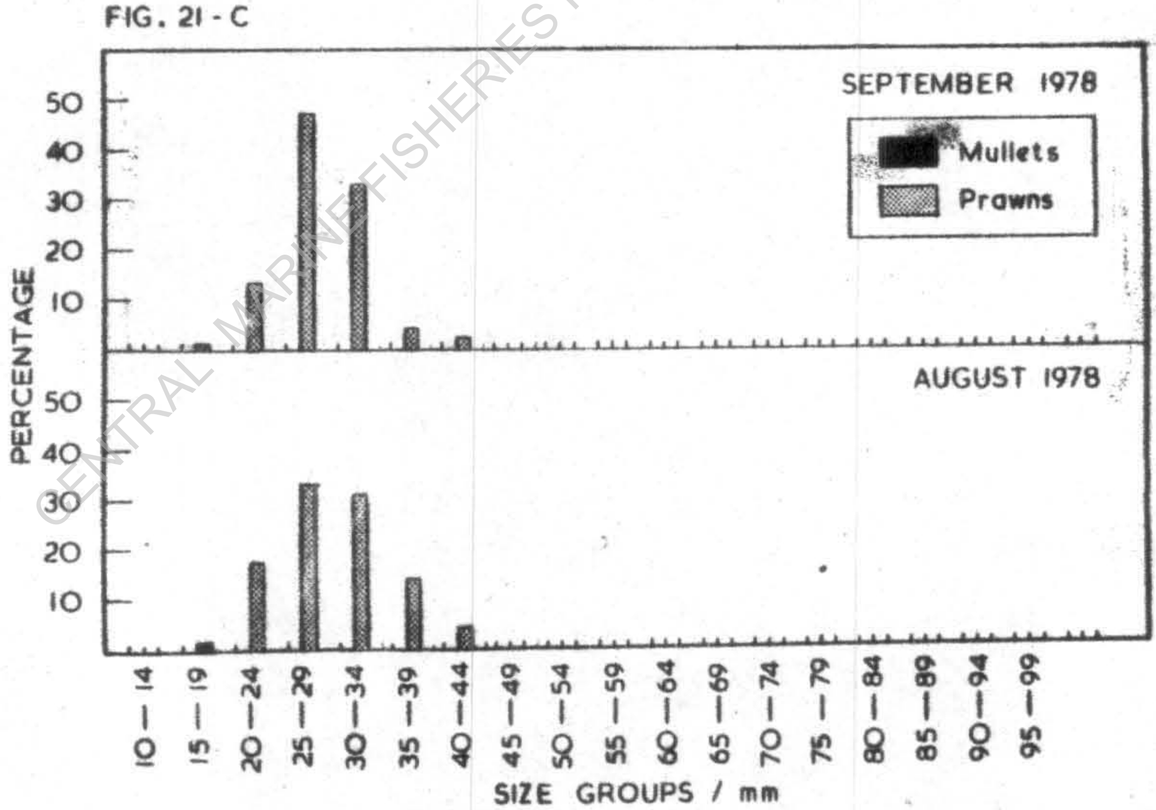


FIG. 21-F

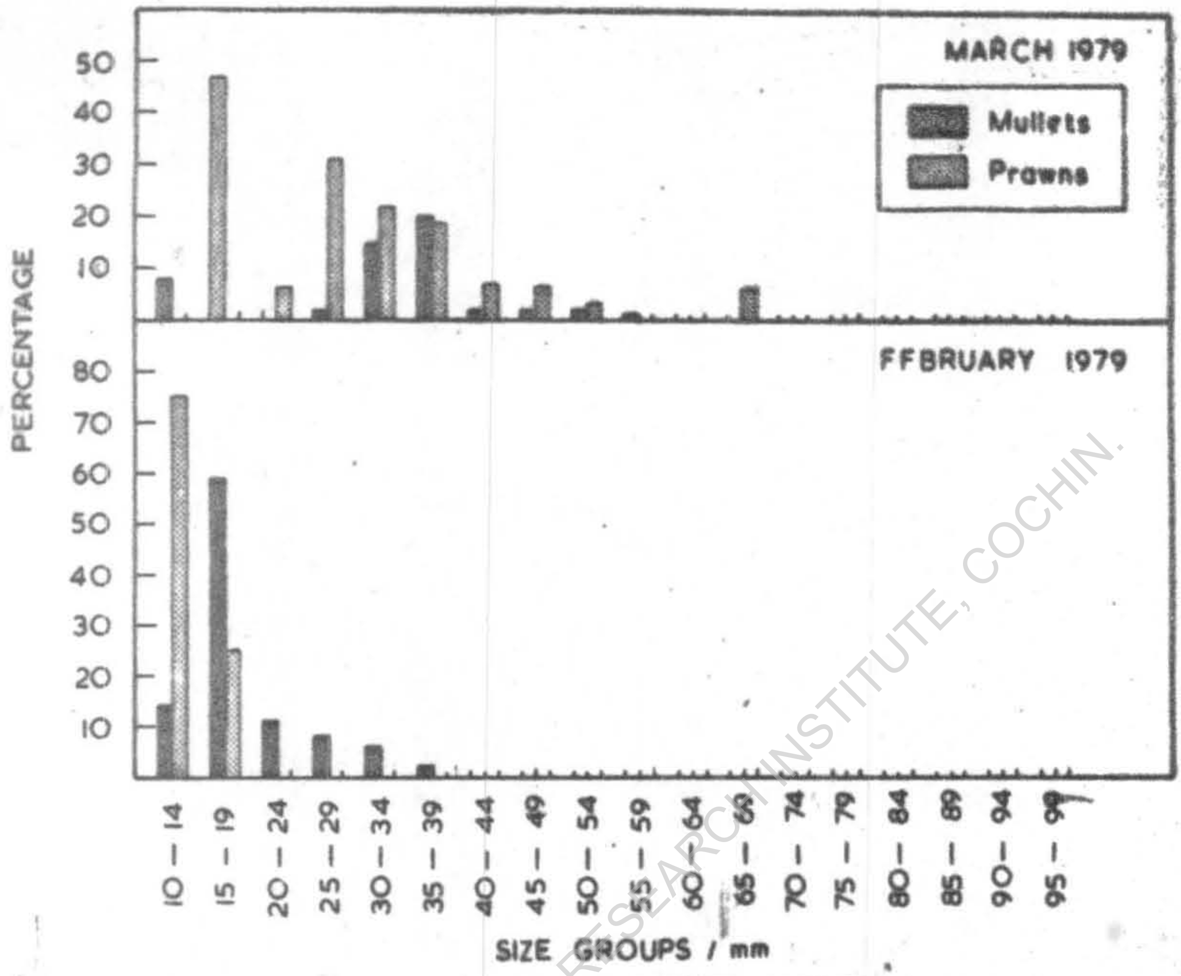


FIG. 21-E

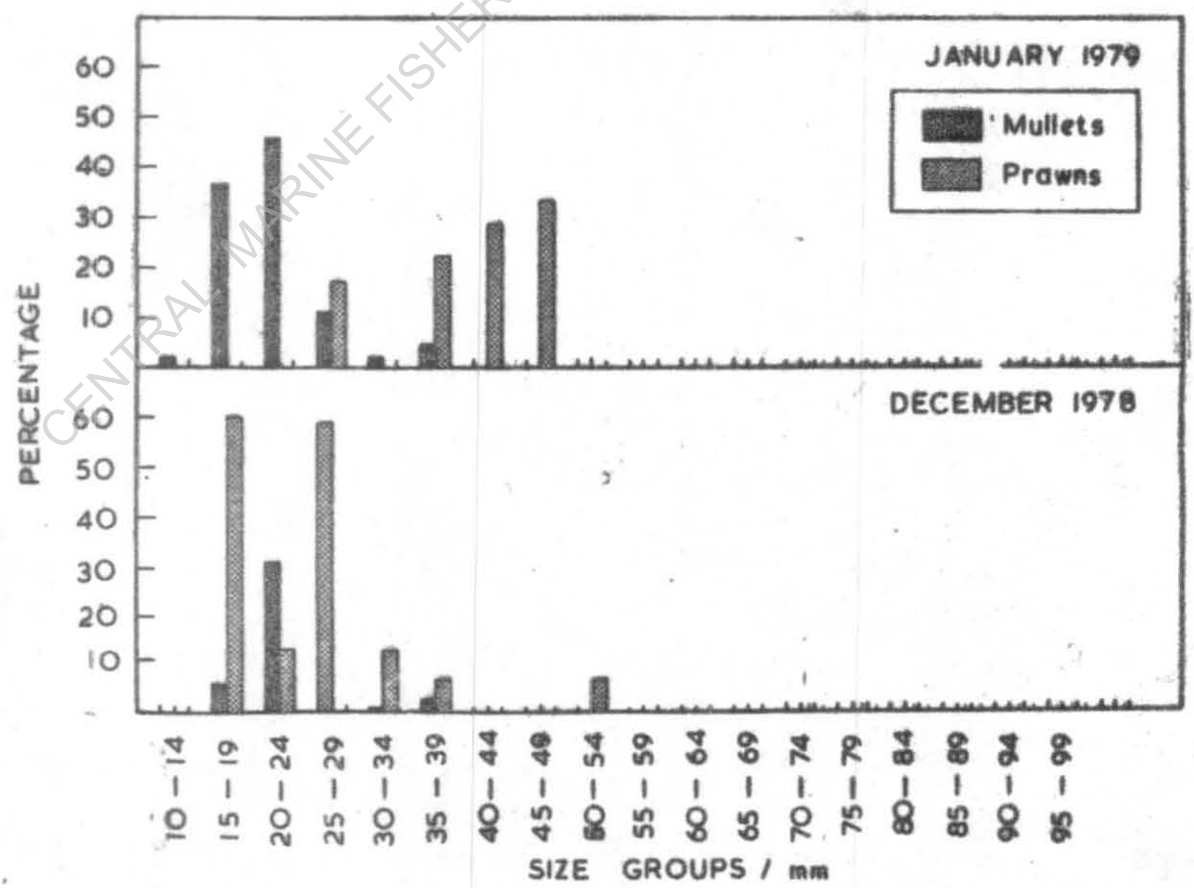


TABLE 13 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET LIZA MACROLEPIS (SMITH) AND PRAWN PENAEUS INDICUS MILNE-EDWARDS IN KOVALAM ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	14.28	-	57.16	-	16.67	-	-	-	-	-	-	-	-	-	3.07	-	11.76	-	-	-	-	-	-	-
15-19	42.85	3.70	14.28	-	53.33	-	-	-	-	-	-	-	-	-	25.38	50.00	52.96	20.00	-	-	28.57	-	-	-
20-24	-	14.81	14.28	50.00	-	-	-	25.00	-	-	-	-	-	-	44.61	-	11.76	26.69	-	-	28.57	26.66	9.09	-
25-29	-	18.51	14.28	-	30.00	42.85	-	25.00	-	-	-	-	-	5.26	26.94	-	5.88	13.33	-	-	7.14	13.33	13.63	-
30-34	-	59.28	-	-	-	-	-	25.00	-	-	-	25.00	-	44.73	-	-	-	13.33	-	-	14.28	13.33	9.09	-
35-39	-	-	-	50.00	-	42.85	-	25.00	-	-	-	25.00	-	23.68	-	-	11.76	13.33	5.00	25.00	14.28	13.33	22.72	-
40-44	14.28	3.70	-	-	-	-	-	-	-	-	-	-	-	2.63	-	50.00	5.88	6.66	30.00	-	7.16	20.03	13.63	-
45-49	21.45	-	-	-	-	14.30	-	-	-	-	-	50.00	-	13.18	-	-	-	-	30.00	50.00	-	6.66	9.09	-
50-54	7.14	-	-	-	-	-	-	-	-	-	-	-	-	10.52	-	-	-	-	20.00	-	-	-	13.66	40.00
55-59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.66	5.00	-	-	6.66	9.09	6.67
60-64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.00	50.00	-	-	-	13.33
65-69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.00

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG 22 A-F SIZE GROUP DISTRIBUTION OF MULLET AND PRAWN IN KOVALAM ESTUARY DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 22 - B

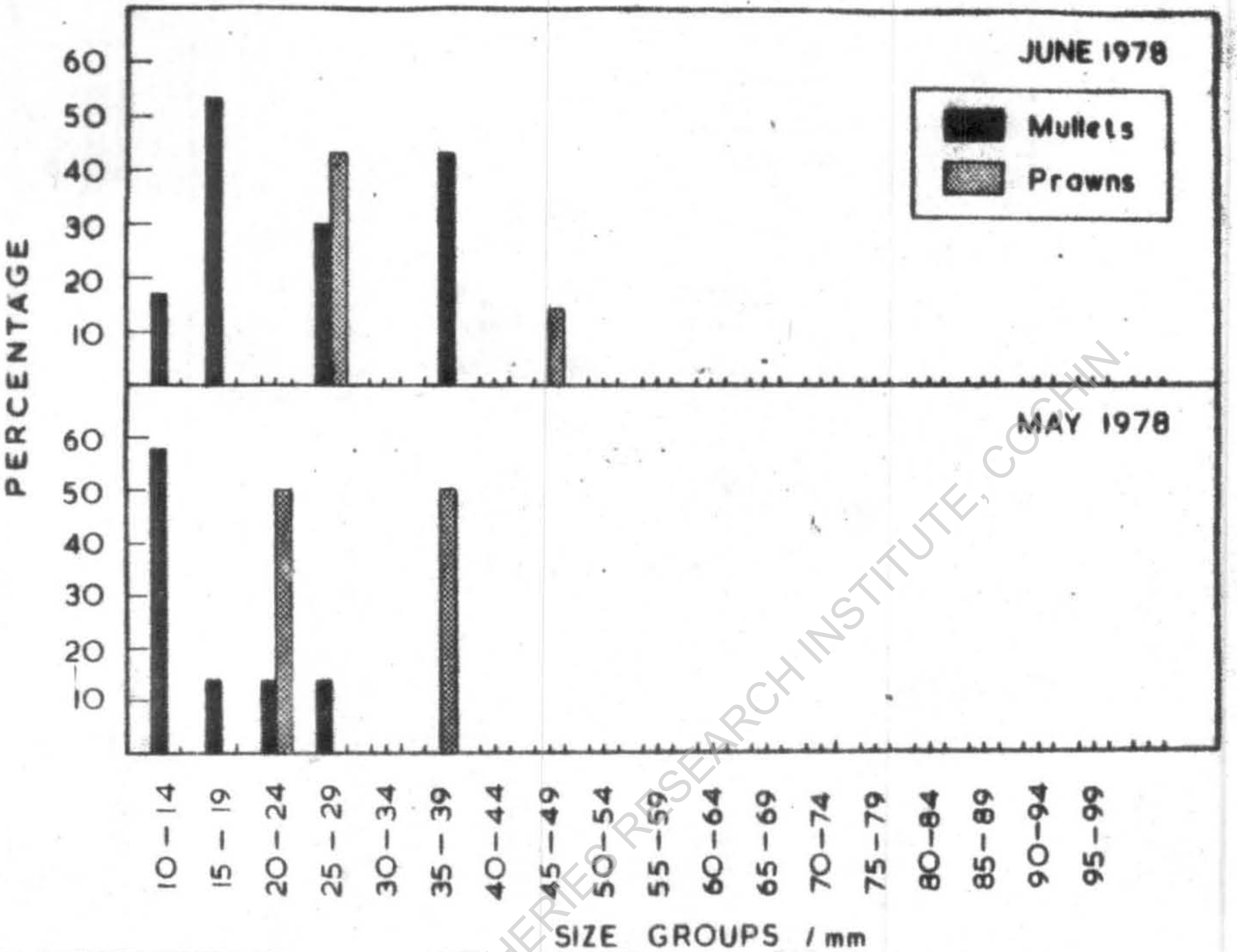


FIG. 22- A

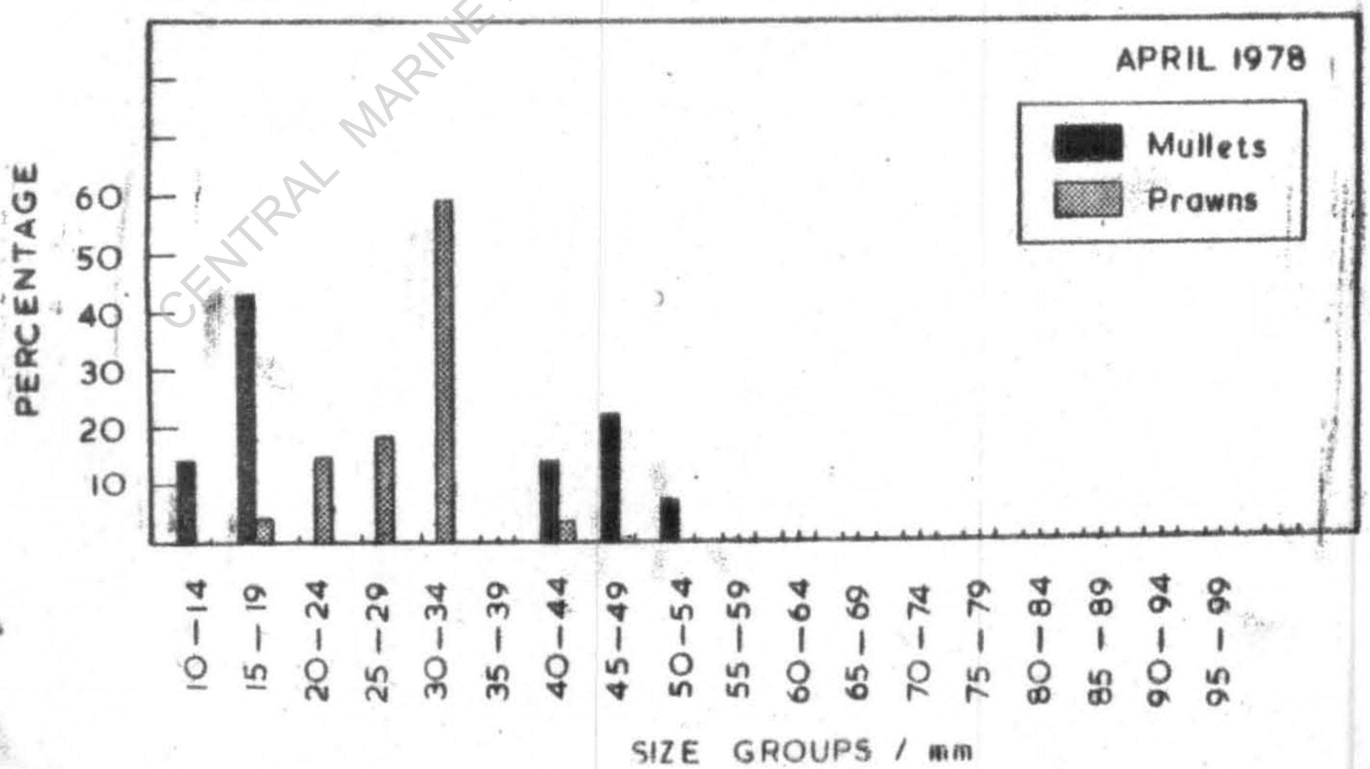


FIG. 22 - D

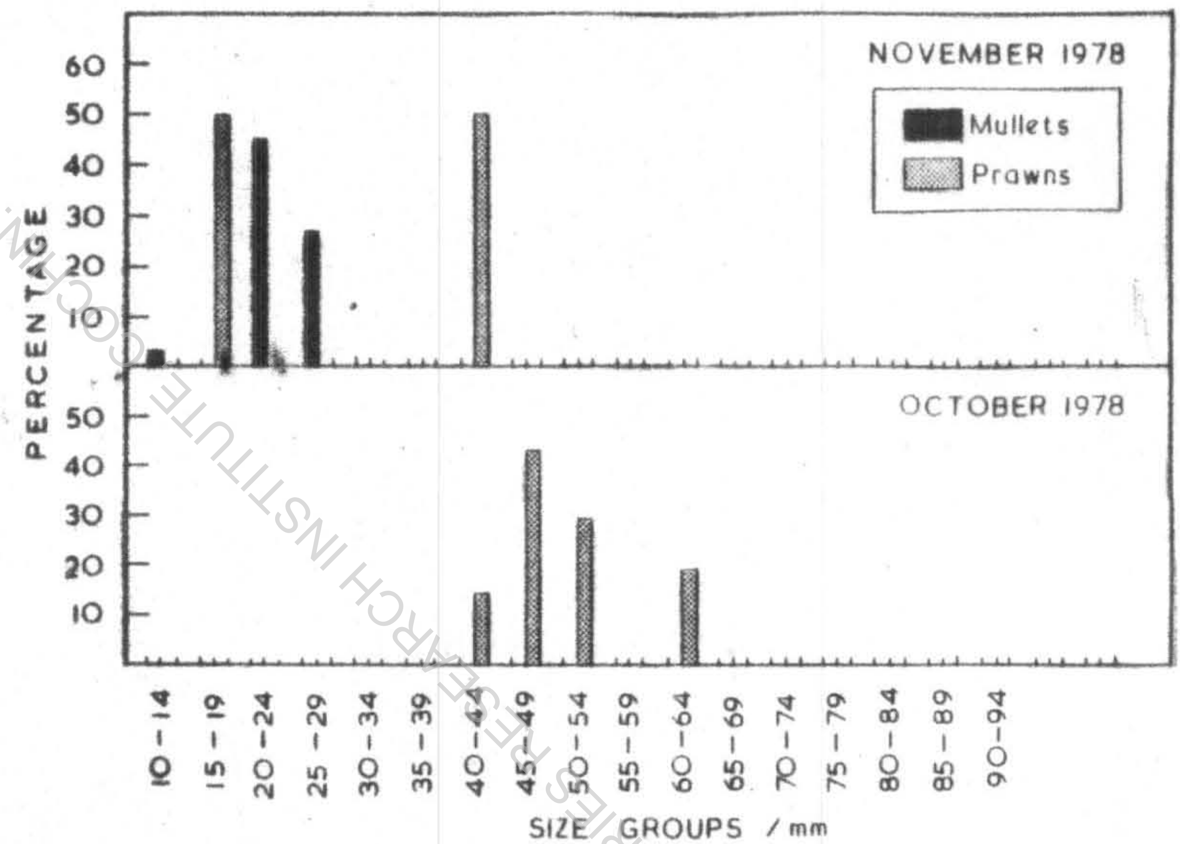
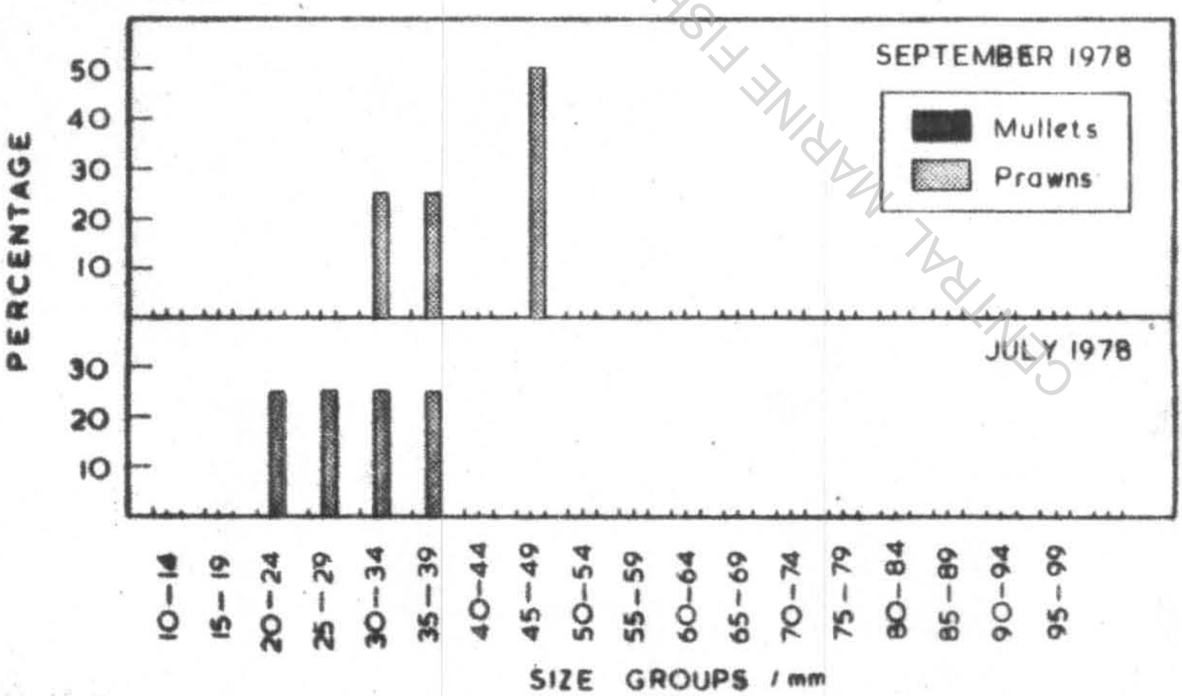


FIG. 22 - C



AUGUST 1978 - nil

FIG. 22-F

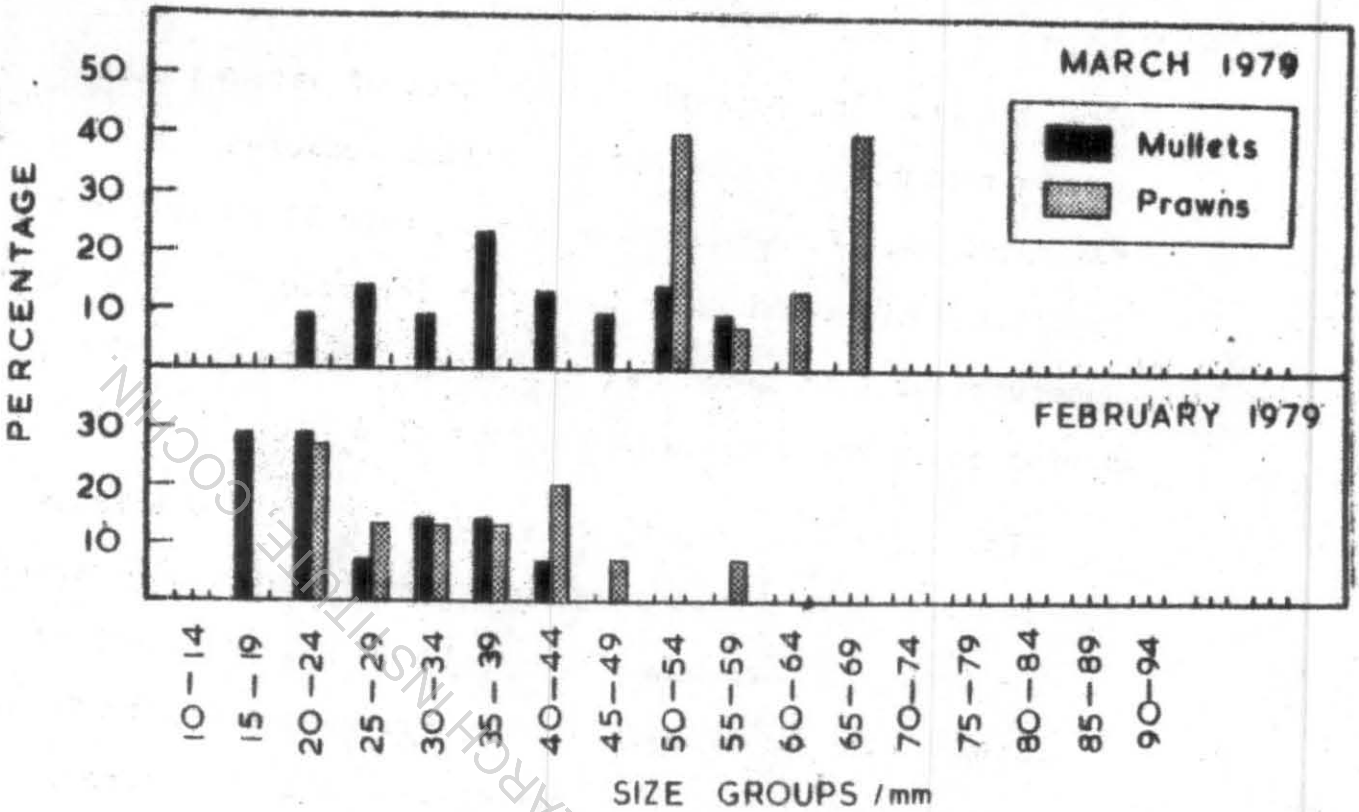
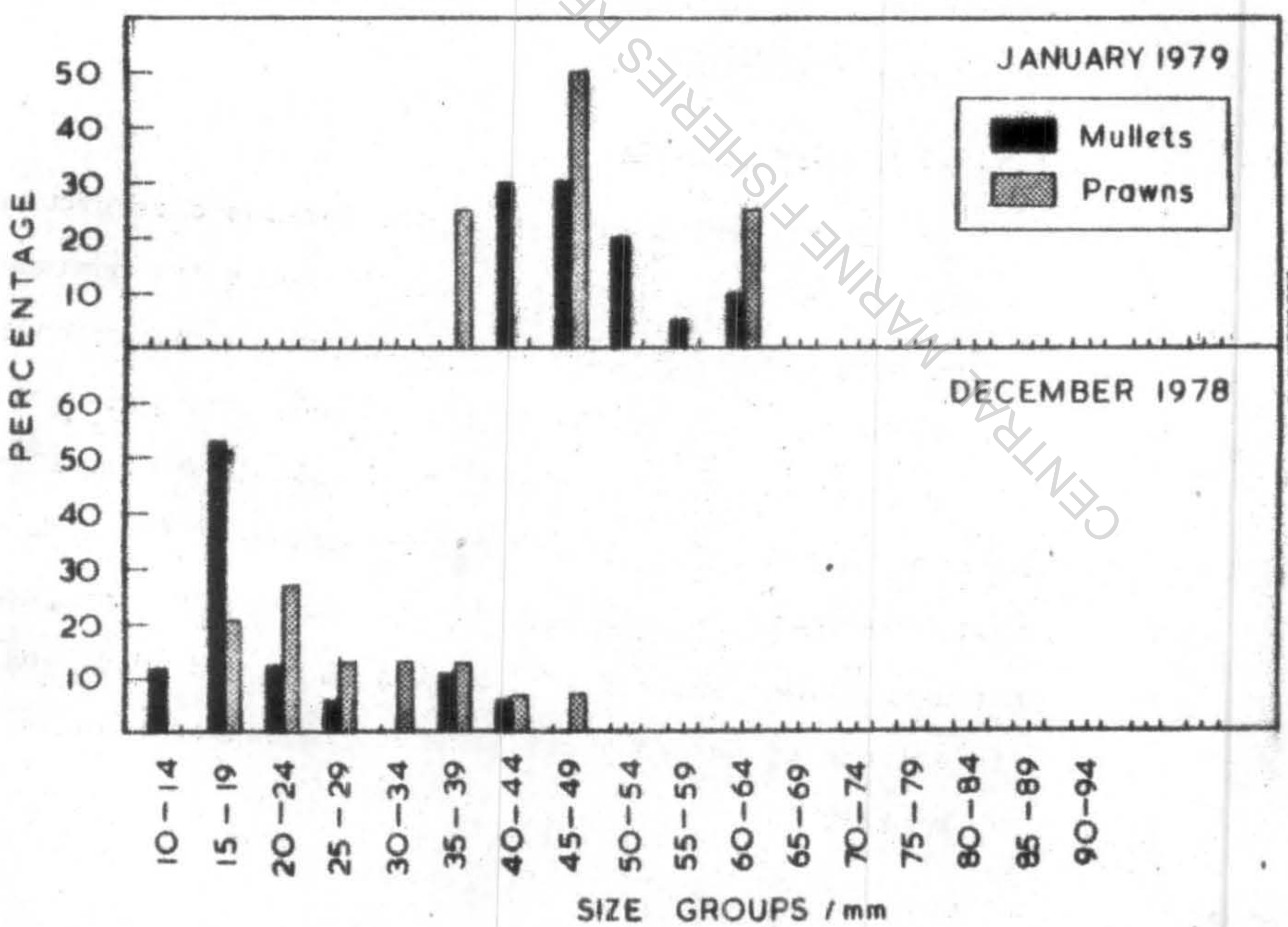


FIG. 22-E



size groups. The pattern of dominance of various size groups resembled as that of the pattern observed in Pulicat lake. Fingerlings measuring over 33 mm showed a restricted distribution. It may be inferred from the above observations that there is a seasonal variation in the dominance of the size groups (Table 12 & Fig. 21 A-F).

The distribution pattern of the fry and fingerlings of the various size groups of prawns showed that the dominance of 10-14 mm size group was seen only during the month of February. Fry and fingerlings measuring about 15 to 39 mm in length were represented uniformly in all the months. Fingerlings of the size group above 45-49 mm showed a restricted distribution.

3.1.2.5 Kovalam estuary

The distribution pattern of the various size groups of the fry and fingerlings of mullets showed the dominance of the size group 10-14 mm only during the month of May. Fry of the size groups 15-19 mm and above were not represented uniformly in all the months (Table 13 & Fig. 22 A-F). Further, the fry and fingerlings of prawns of the size groups 10-14 and 15-19 mm were not represented as dominant groups throughout the year. Fry measuring 20 mm and above and fingerlings 40 mm and above were poorly represented in all the months.

TABLE 14 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET <u>LIZA MACROLEPIS</u> (SMITH) AND PRAWN <u>PENAEUS INDICUS</u> MILNE-EDWARDS IN EDAYUR ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	30.00	-	-	-	1.63	-	-	-	7.14	-	-	-	-	-	-	-	4.34	-	-	-	-	-	13.63	-
15-19	37.50	50.00	33.34	-	59.83	41.66	-	-	-	-	-	-	-	-	-	-	26.08	-	3.50	-	-	-	64.09	-
20-24	22.50	-	25.00	33.33	5:77	-	-	61.53	14.28	-	-	-	-	-	-	33.34	60.89	33.33	52.63	66.66	-	-	-	20.00
25-29	2.50	-	16.66	33.33	24.59	33.34	-	-	35.73	-	-	-	-	-	-	66.66	8.69	40.00	8.77	-	-	-	12.28	20.00
30-34	5.00	-	25.00	-	8.19	25.00	-	23.09	37.50	-	-	-	-	-	-	-	-	26.67	14.03	33.34	-	23.52	-	20.00
35-39	2.50	50.00	-	16.67	-	-	-	-	5.35	-	-	-	-	-	-	-	-	-	17.54	-	-	35.29	-	20.00
40-44	-	-	-	16.67	-	-	20.00	15.38	-	-	-	-	-	14.28	-	-	-	-	3.50	-	-	17.67	-	20.00
45-49	-	-	-	-	-	-	40.00	-	-	-	-	-	-	42.87	-	-	-	-	-	-	-	-	-	-
50-54	-	-	-	-	-	-	20.00	-	-	-	-	-	-	28.57	-	-	-	-	-	-	-	11.76	-	-
55-59	-	-	-	-	-	-	20.00	-	-	-	-	-	-	-	-	-	-	-	-	-	3,57	11.76	-	-
60-64	-	-	-	-	-	-	20.00	-	-	-	-	-	-	14.28	-	-	-	-	-	-	3.57	-	-	-
65-69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.14	-	-	-
70-74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.85	-	-	-
75-79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.28	-	-	-
80-84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.28	-	-	-
85-89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.28	-	-	-
90-94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.75	-	-	-
95-99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.28	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG. 23. A - F SIZE GROUP DISTRIBUTION OF MULLET AND PRAWN IN EDAYUR ESTUARY DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 23 - B

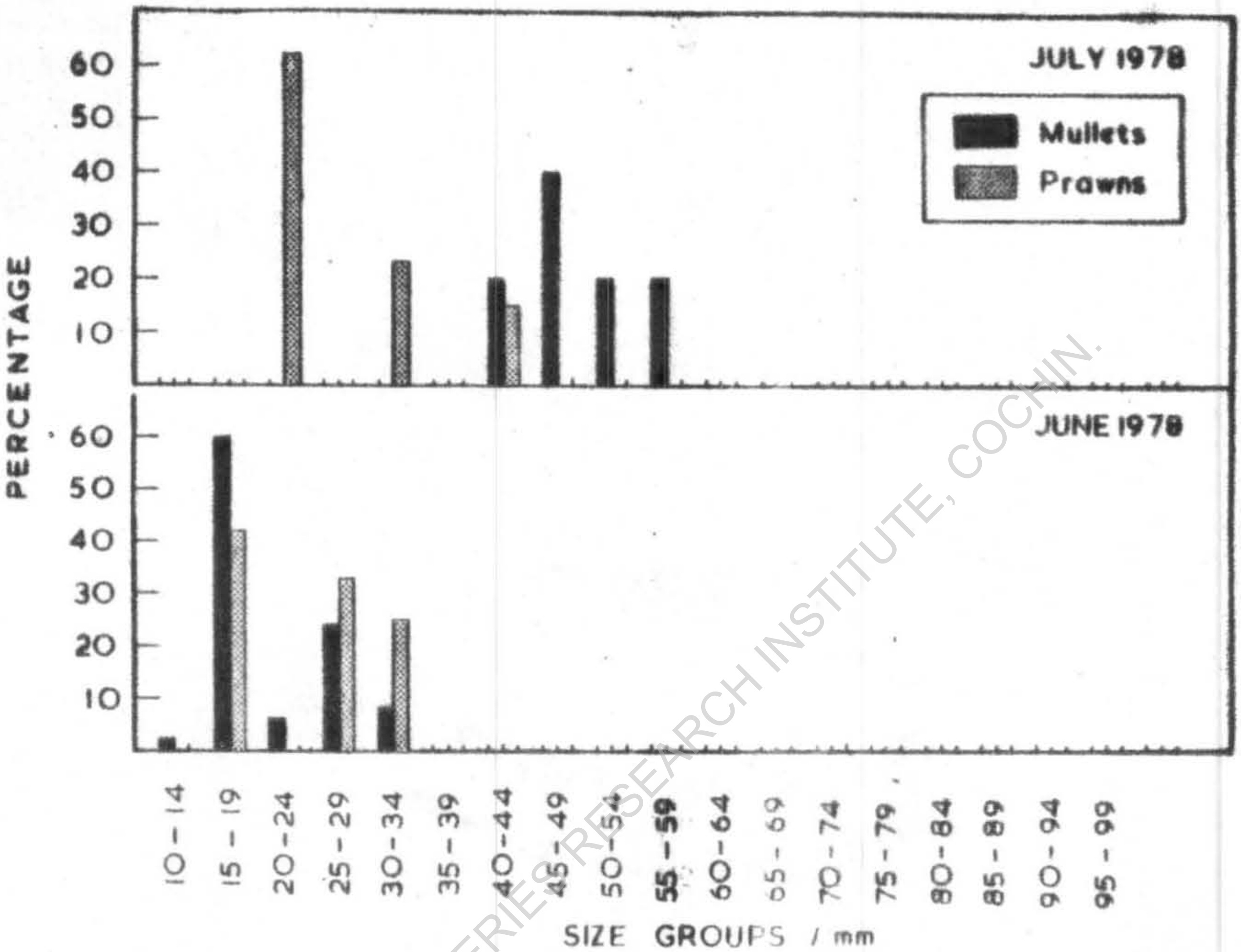


FIG. 23 - A

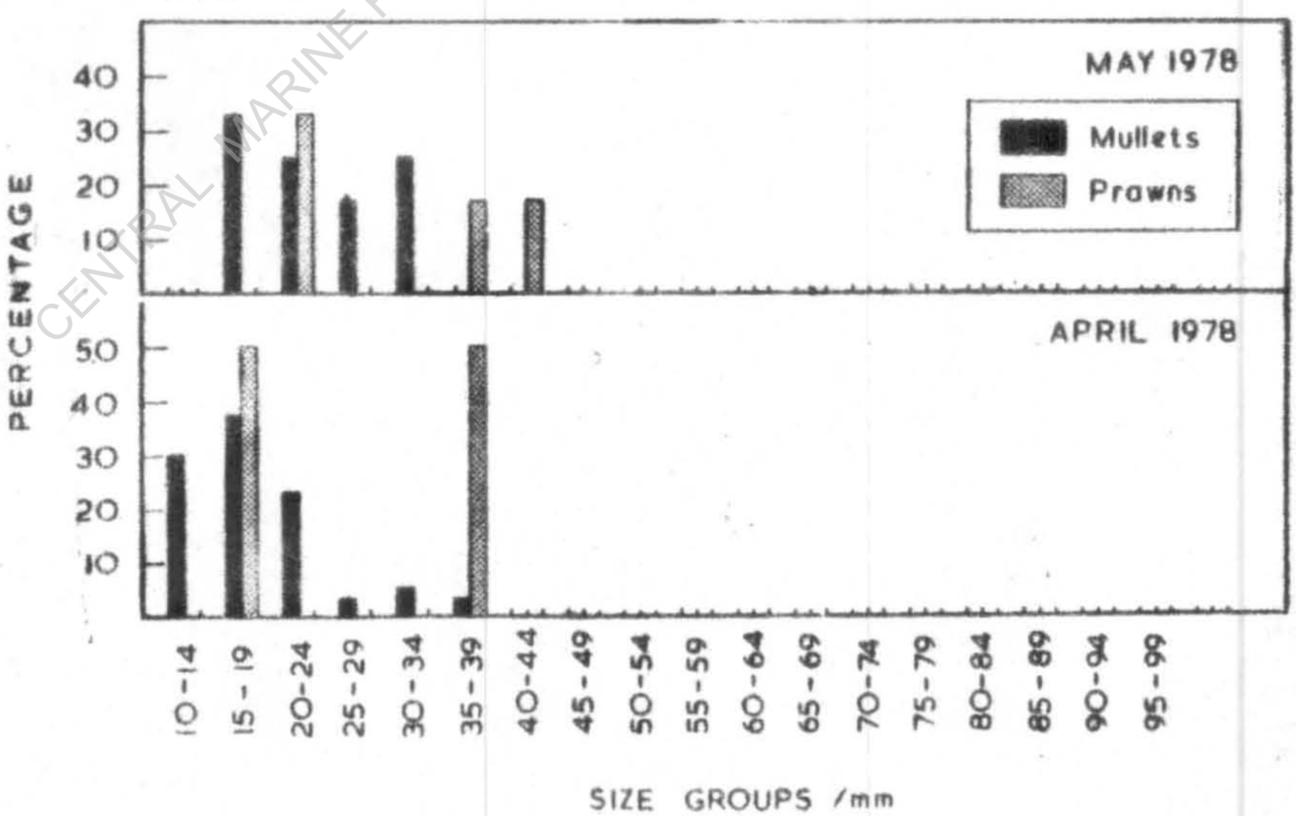


FIG. 23 - D

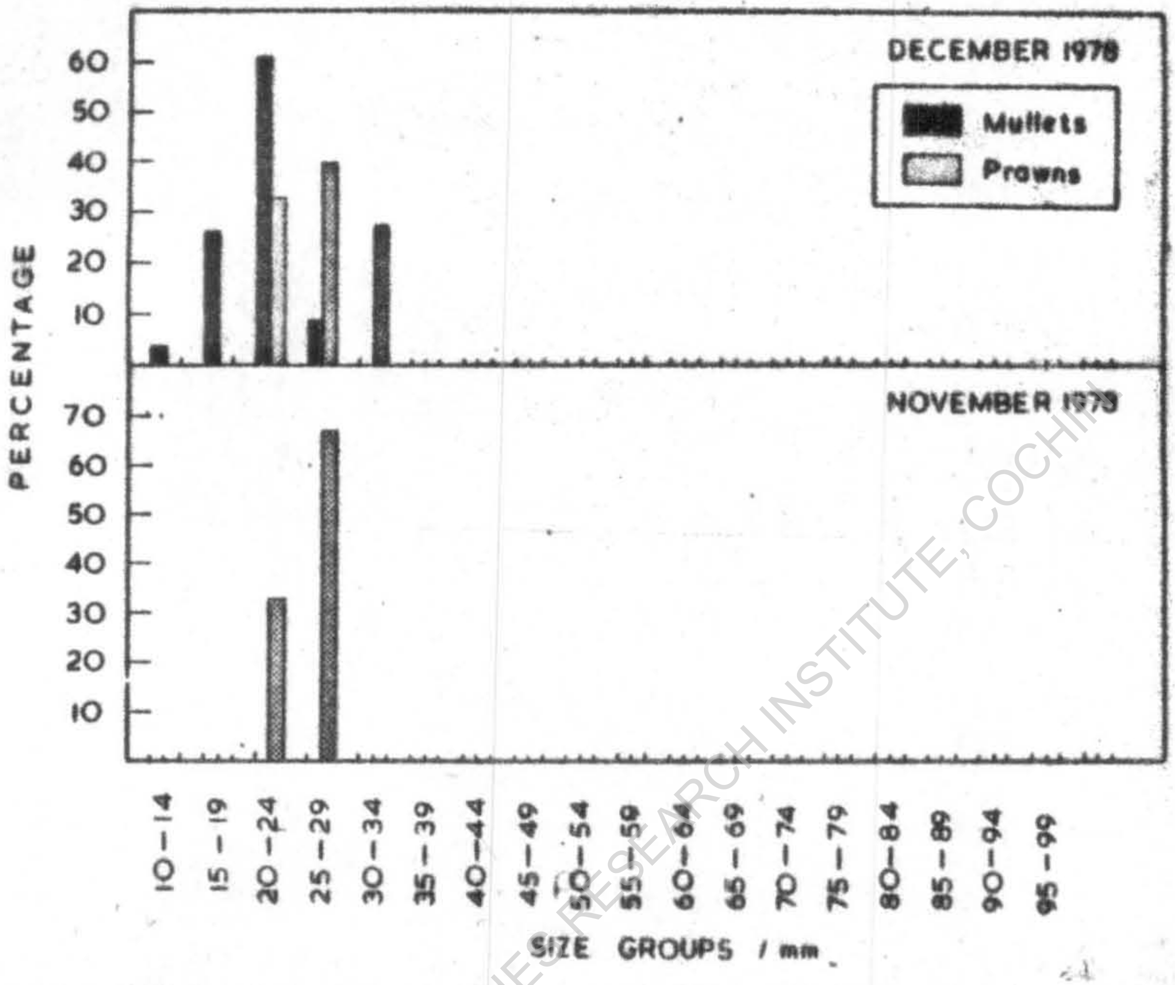
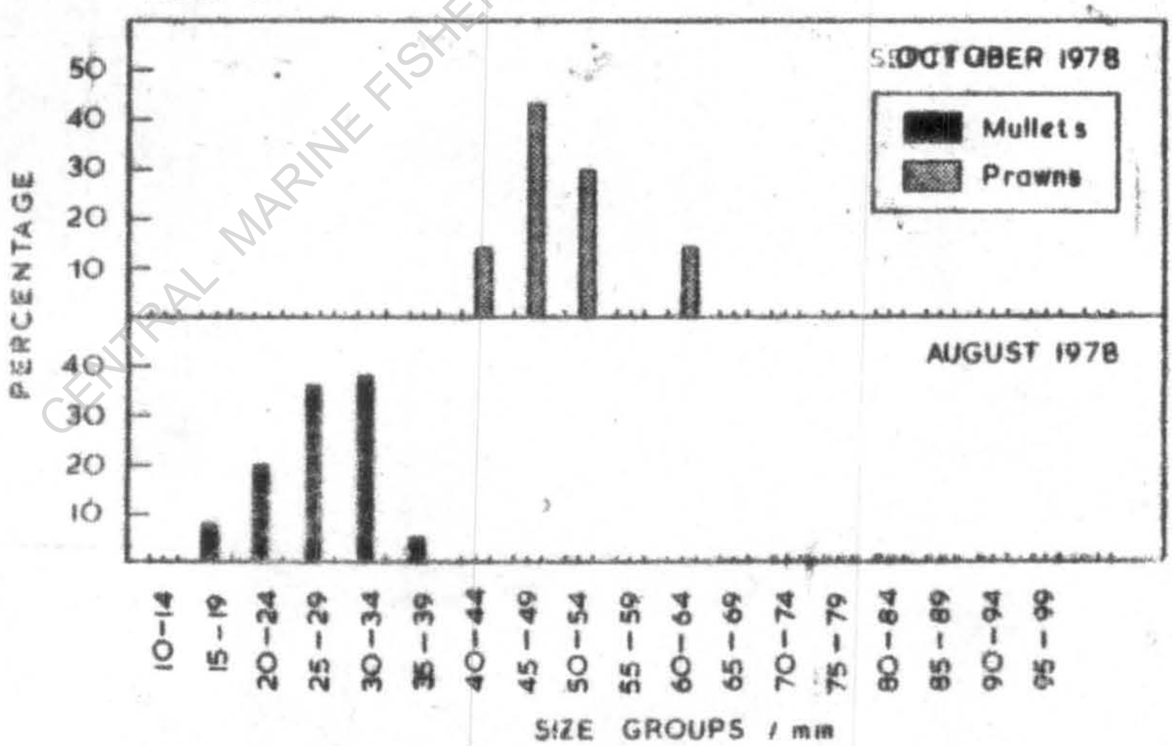


FIG. 23 - C



SEPTEMBER 1978 - nil

FIG. 23-F

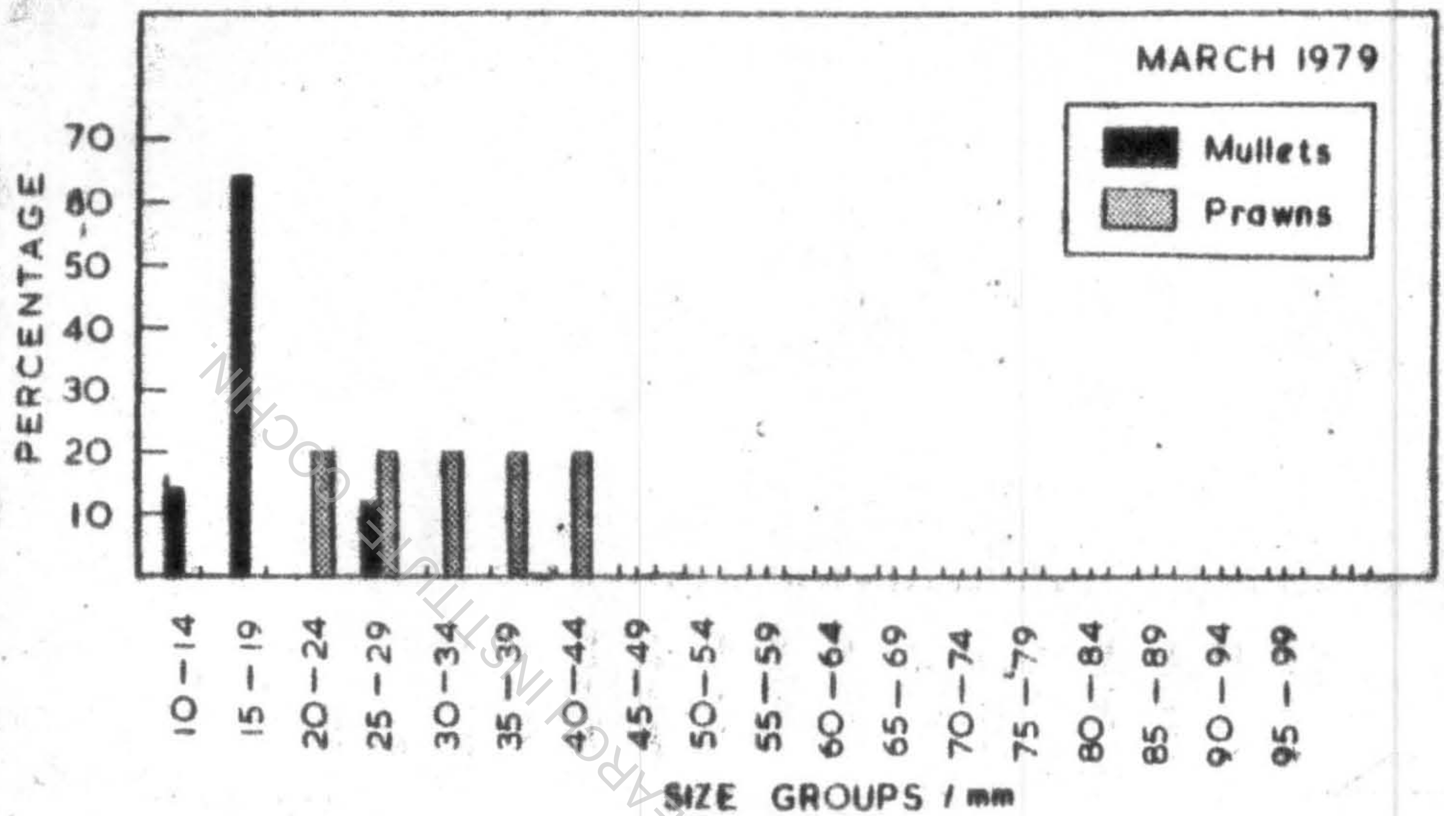


FIG. 23-E

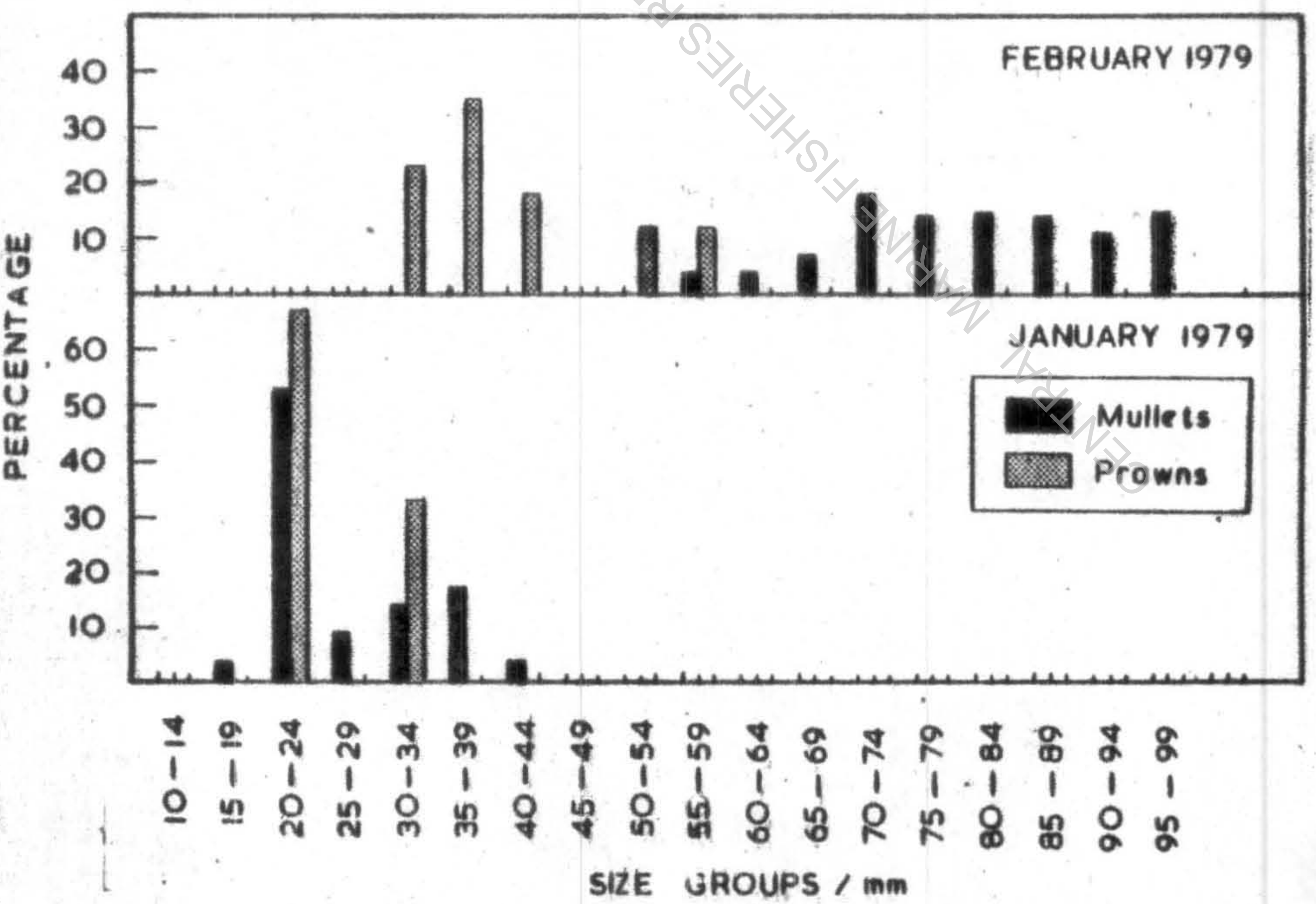


TABLE 15 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET *LIZA MACROLEPIS* (SMITH) AND PRAWN *PENAEUS INDICUS* MILNE-EDWARDS IN SADRAS ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	-	10.00	-	37.50	-	-	-	-	-	-	-	-	-	-	71.81	-	-	-	-	-	-	-	-	-
15-19	-	60.00	-	-	71.44	22.22	-	-	14.28	-	-	-	-	-	9.09	-	55.55	15.09	-	-	-	-	-	-
20-24	-	30.00	-	25.00	5.71	33.33	60.00	11.76	35.71	14.28	24.28	-	-	-	19.09	14.28	22.23	16.98	-	33.33	-	40.00	-	-
25-29	-	-	-	12.50	23.85	33.33	-	17.64	21.45	28.59	75.72	25.00	-	-	-	-	-	22.64	-	-	-	40.00	-	-
30-34	-	-	-	12.50	-	11.12	20.00	33.33	-	-	-	-	-	-	-	57.00	-	24.54	-	50.00	-	20.00	-	-
35-39	-	-	-	-	-	-	20.00	13.76	7.17	-	-	-	-	-	-	14.28	11.11	11.35	-	16.67	-	-	-	-
40-44	-	-	-	-	-	-	-	10.78	-	-	-	-	-	-	-	-	-	7.54	30.78	-	-	-	-	-
45-49	-	-	-	12.50	-	-	-	4.90	-	-	-	-	-	-	-	-	11.11	1.88	46.15	-	-	-	-	-
50-54	-	-	-	-	-	-	-	5.88	14.28	14.28	-	16.66	-	20.00	-	14.42	-	-	23.07	-	-	-	-	-
55-59	-	-	-	-	-	-	-	-	7.14	28.57	-	8.36	-	10.00	-	-	-	-	-	-	-	-	-	-
60-64	-	-	-	-	-	-	-	-	-	14.28	-	16.66	-	40.00	-	-	-	-	-	-	-	-	-	-
65-69	-	-	-	-	-	-	1.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70-74	-	-	50.00	-	-	-	-	-	-	-	-	16.66	-	10.00	-	-	-	-	-	-	25.00	-	-	-
75-79	-	-	-	-	-	-	-	-	-	-	-	-	-	20.00	-	-	-	-	-	-	-	-	-	-
80-84	-	-	-	-	-	-	-	-	-	-	-	16.66	-	-	-	-	-	-	-	-	50.00	-	-	-
85-89	-	-	50.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.00	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG. 24 A-F SIZE GROUP DISTRIBUTION OF MULLET AND PRAWNS SADRAS ESTUARY DURING THE PERIOD OF SURVEY APRIL 1978 TO MARCH 1979

FIG. 24 - B

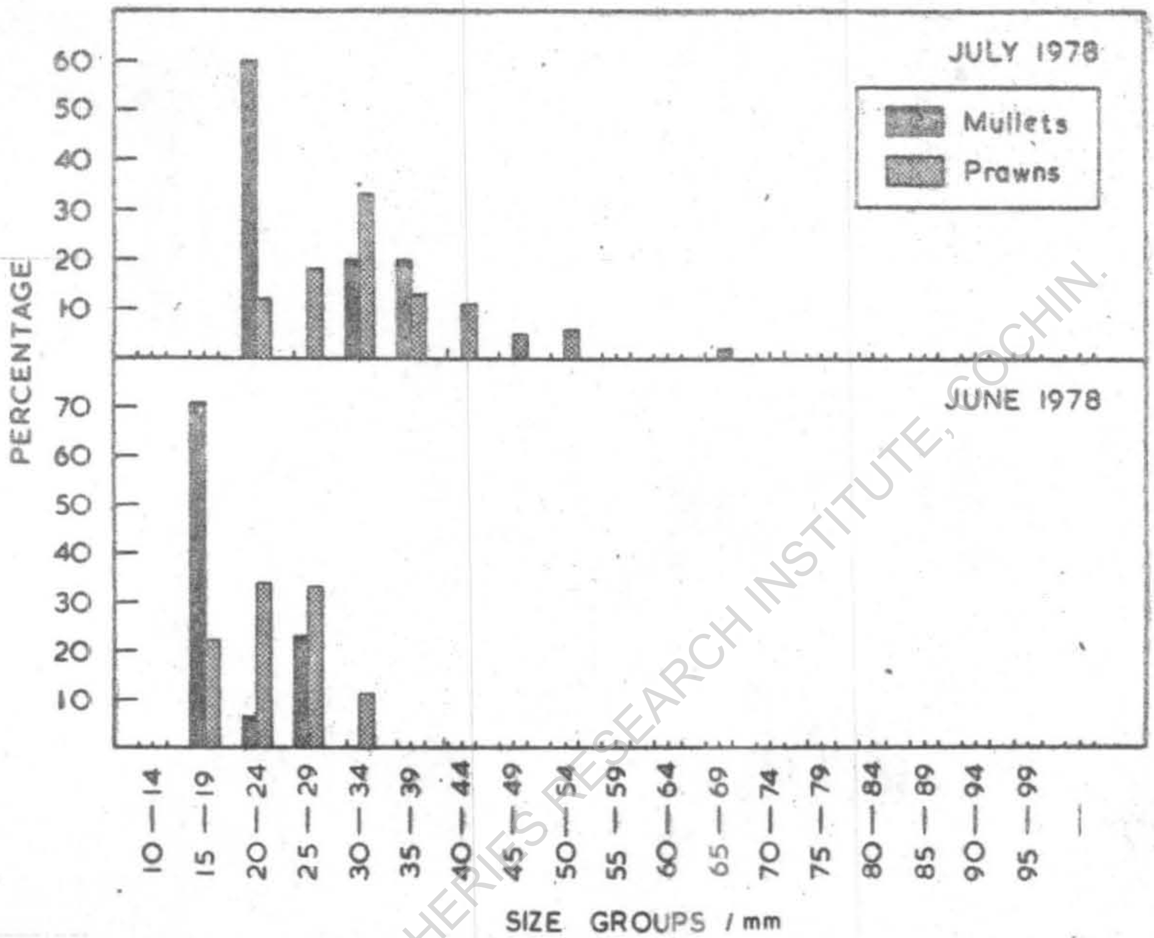


FIG. 24 - A

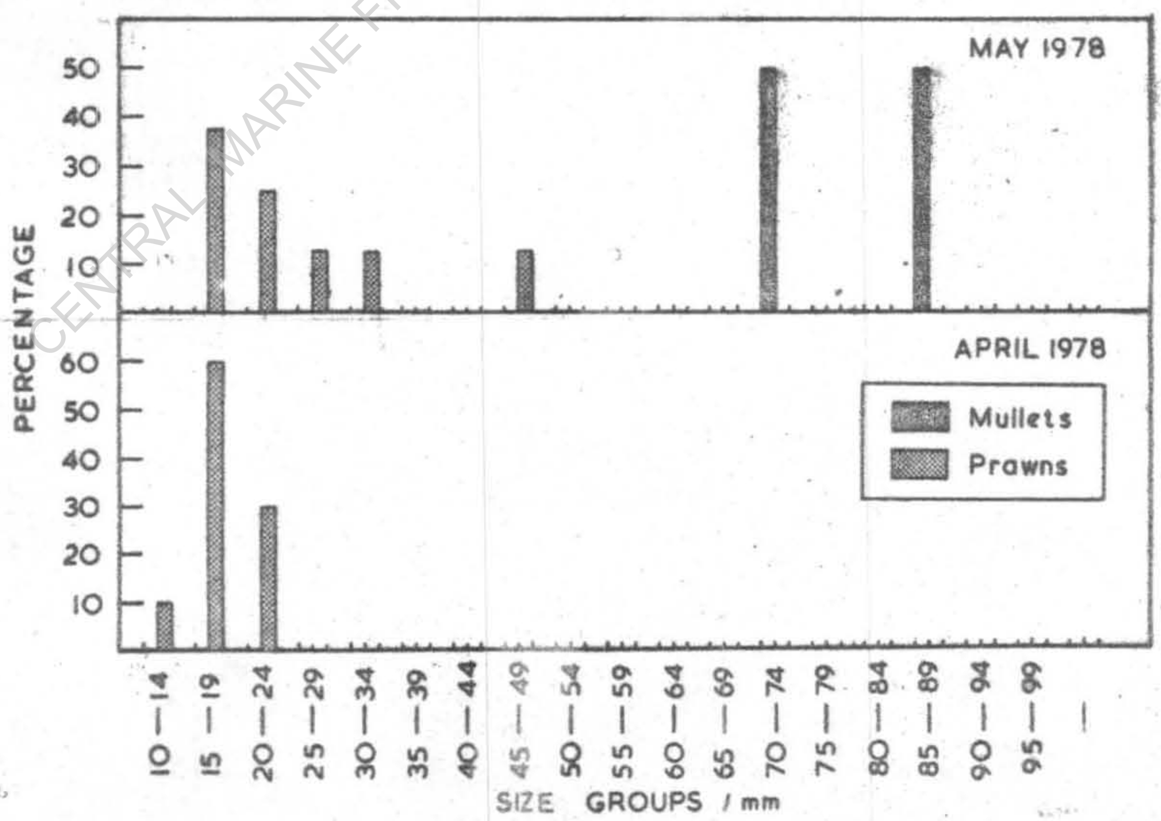


FIG. 24 - D

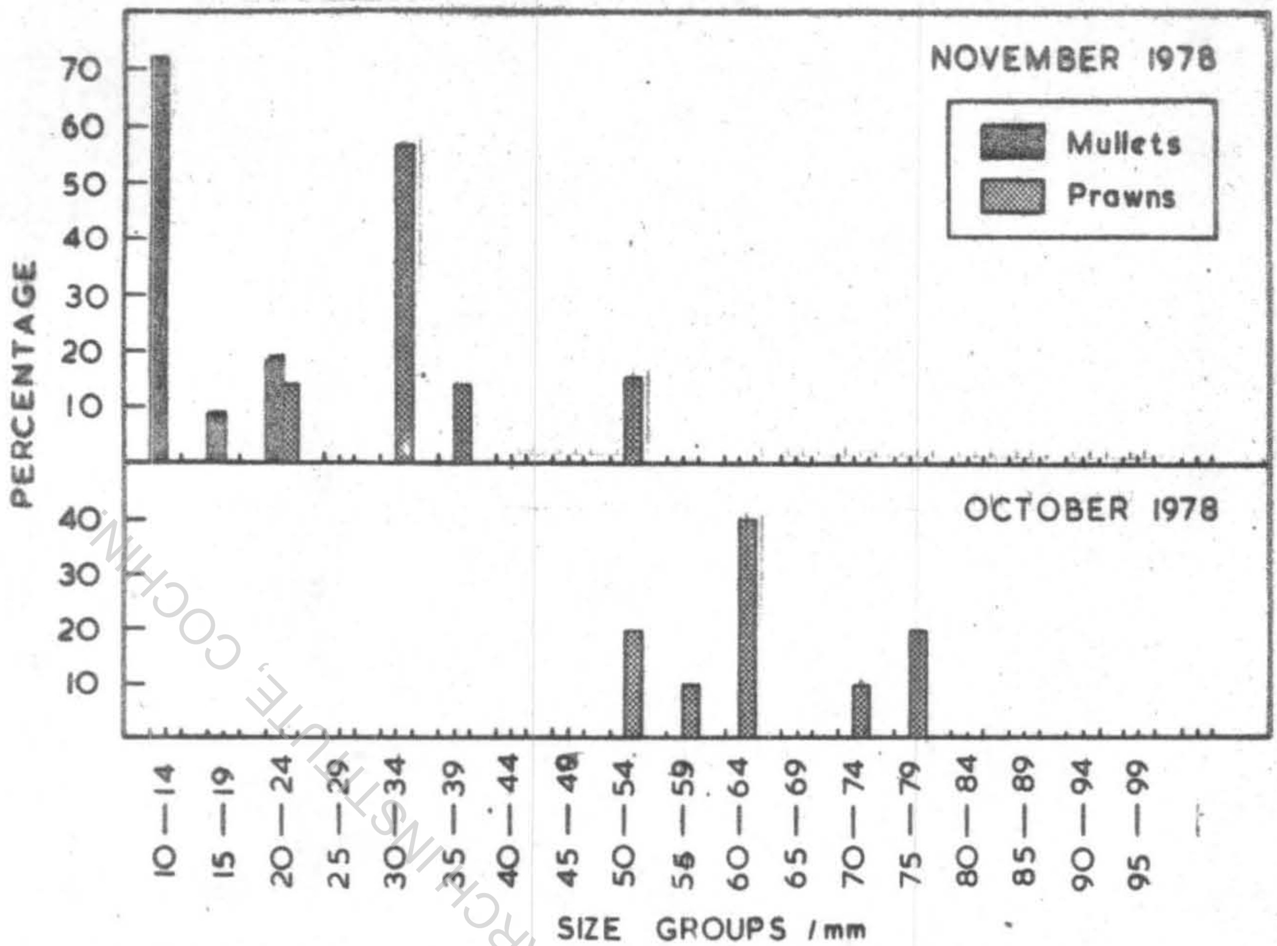


FIG. 24 - C

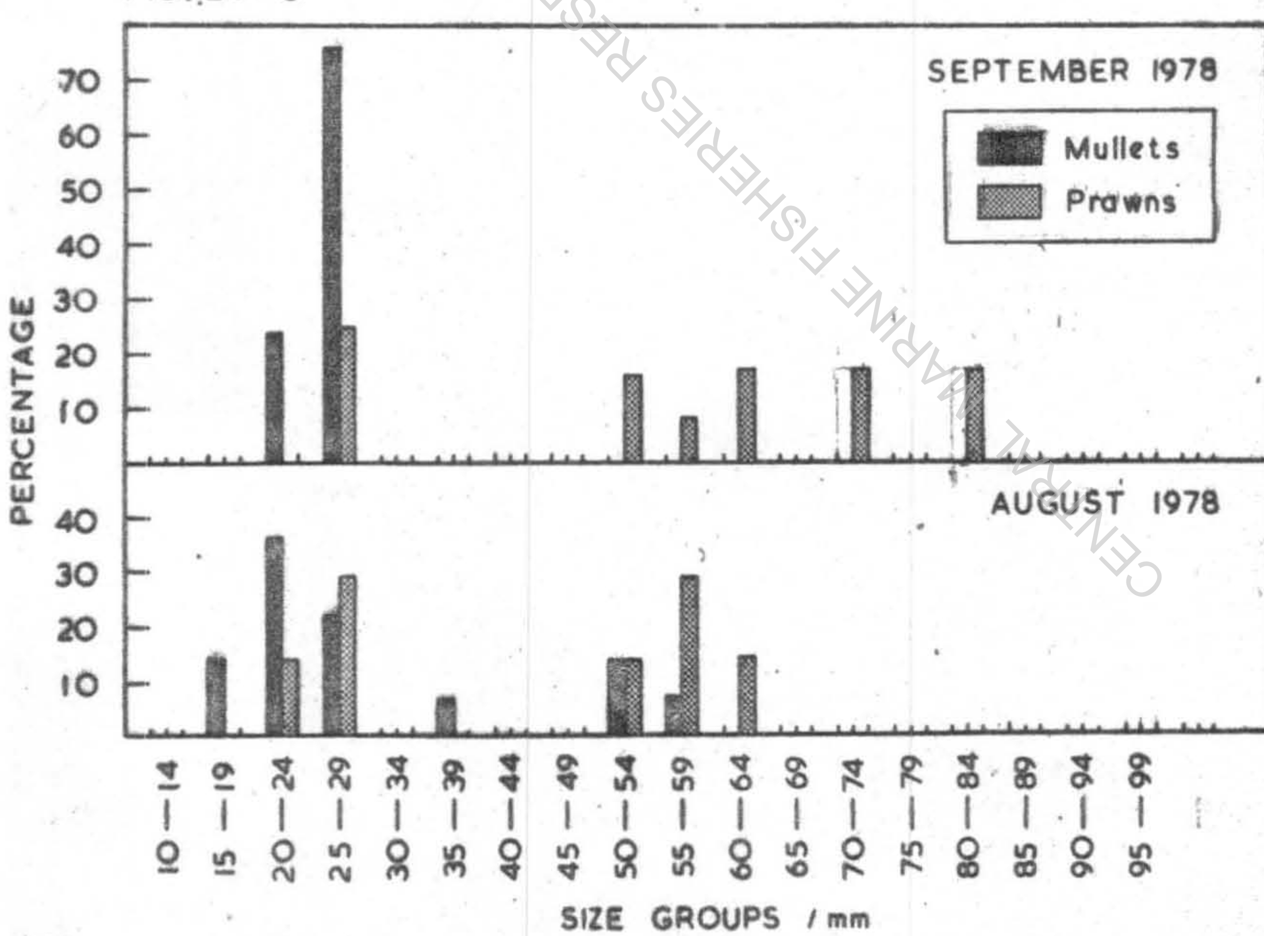


FIG. 24 - F

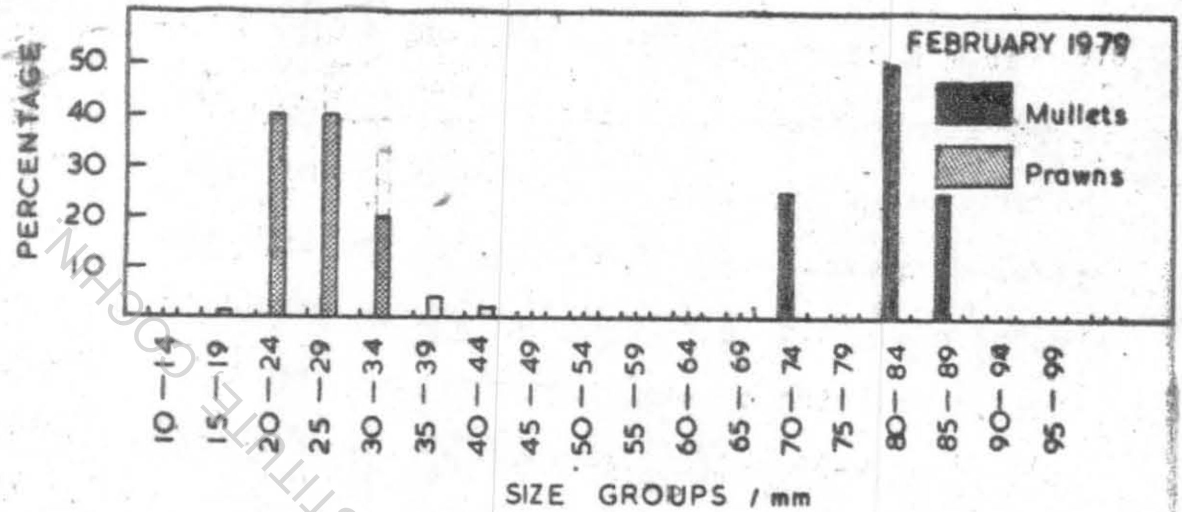
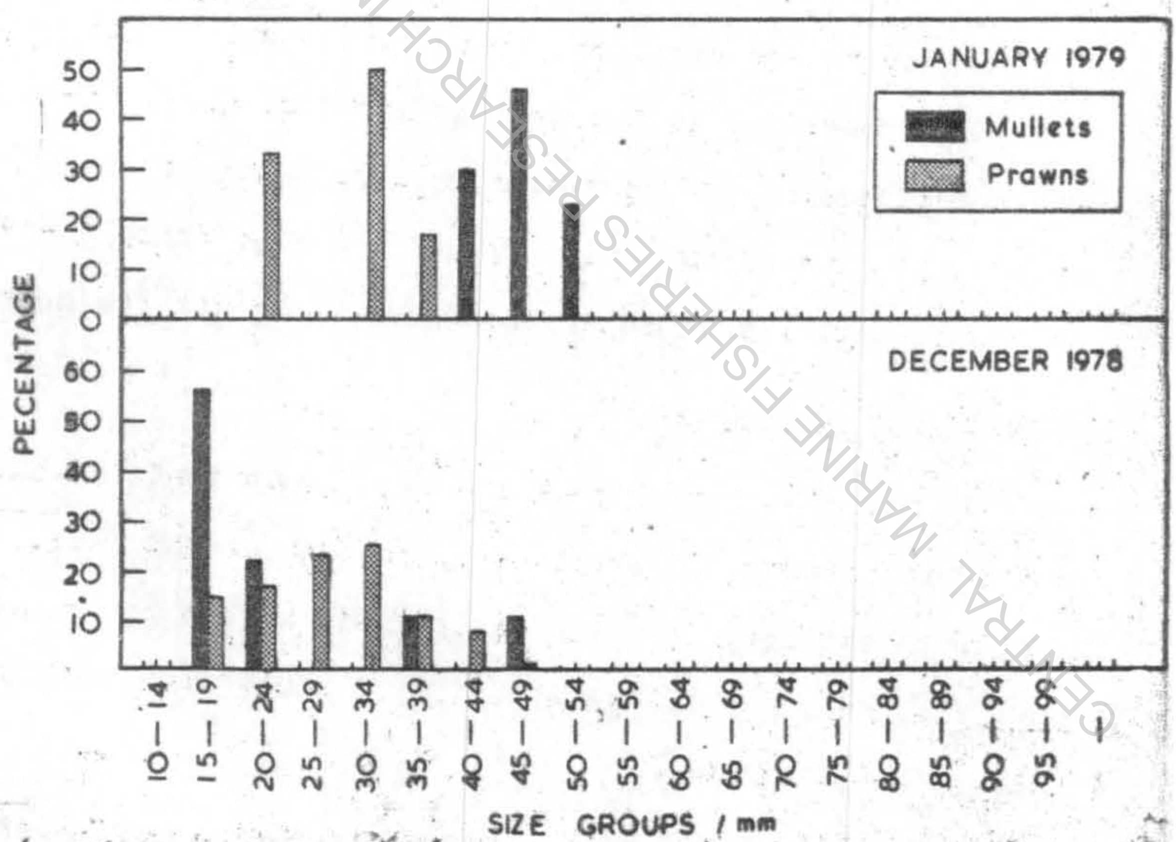


FIG. 24 - E



MARCH 1979 - nil

3.1.2.6 Edayur estuary

It may be observed from Table 14 & Fig. 23 A-F that in the length frequency distribution pattern, the fry of the size group 10-14 mm was not represented as a dominant group. The occurrence of the fry of the size group 15-19 mm and above was not represented uniformly in all the months. It is interesting to note that the fingerlings of the size group from 55-99 mm were recorded in large numbers during the month of February.

It may be seen from the distribution pattern of the fry and fingerlings of prawns that the size group 10-14 mm was not represented as dominant groups, a pattern which recalls as that of mullets. Fry of the size group 15-19 mm and above were not represented uniformly in all the months.

3.1.2.7 Sadras estuary

It may be observed that the size group 10-14 mm was not represented as dominant group throughout the year. As mentioned earlier, the size group 15-19 mm was not represented uniformly during the entire period of study (Table 15 & Fig. 24 A-F).

The distribution pattern of fry and fingerlings of prawns showed that the size group 10-14 mm was not represented as dominant group throughout the year. Prawn fry of the size

TABLE 16 DISTRIBUTION PATTERN OF VARIOUS SIZE GROUPS OF MULLET LIZA MACROLEPIS (SMITH) AND PRAWN PENAEUS INDICUS MILNE-EDWARDS IN PALAR ESTUARY (APRIL 1978 TO MARCH 1979)

SIZE GROUPS (mm)	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)	M (%)	P (%)
10-14	15.00	22.22	10.00	44.44	11.42	-	-	-	50.00	-	-	-	-	-	58.12	-	0.35	-	-	-	-	-	-	-
15-19	-	-	-	33.33	11.42	42.85	2.85	2.70	-	-	-	25.00	-	-	25.63	-	4.27	-	-	-	-	-	30.18	-
20-24	35.00	-	25.00	-	1.42	28.57	66.66	24.32	30.00	-	-	25.00	25.00	29.43	16.25	4.30	70.44	-	40.00	-	-	-	33.96	-
25-29	-	-	-	-	41.44	-	15.28	35.13	-	-	-	12.50	8.33	11.76	-	6.12	24.94	-	-	-	15.62	-	28.30	-
30-34	-	33.33	-	5.55	34.28	28.58	1.90	29.75	-	-	-	12.50	-	5.88	-	10.75	-	-	-	16.00	68.75	-	7.54	-
35-39	20.00	-	25.00	16.68	-	-	1.90	-	20.00	-	-	-	16.66	5.88	-	10.75	-	-	-	16.00	9.37	-	-	-
40-44	-	-	5.00	-	-	-	0.95	2.70	-	-	-	-	-	5.88	-	4.30	-	-	20.00	32.00	6.25	-	-	-
45-49	-	44.45	-	-	-	-	-	-	-	-	-	-	16.66	11.76	-	8.60	-	-	-	-	-	-	-	-
50-54	-	-	5.00	-	-	-	3.80	-	-	-	-	-	8.33	29.41	-	15.05	-	-	-	-	-	-	-	-
55-59	-	-	-	-	-	-	6.66	-	-	-	-	12.50	8.33	-	-	17.20	-	-	-	16.00	-	-	-	-
60-64	-	-	-	-	-	-	-	5.40	-	-	-	-	-	-	-	9.67	-	-	-	16.00	-	-	-	-
65-69	-	-	30.00	-	-	-	-	-	-	-	-	-	16.69	-	-	3.26	-	-	-	4.00	-	-	-	-
70-74	30.00	-	-	-	-	-	-	-	-	-	-	12.50	-	-	-	-	-	-	40.00	-	-	-	-	-

M=DENOTES MULLETS

P=DENOTES PRAWNS

FIG. 25 - D

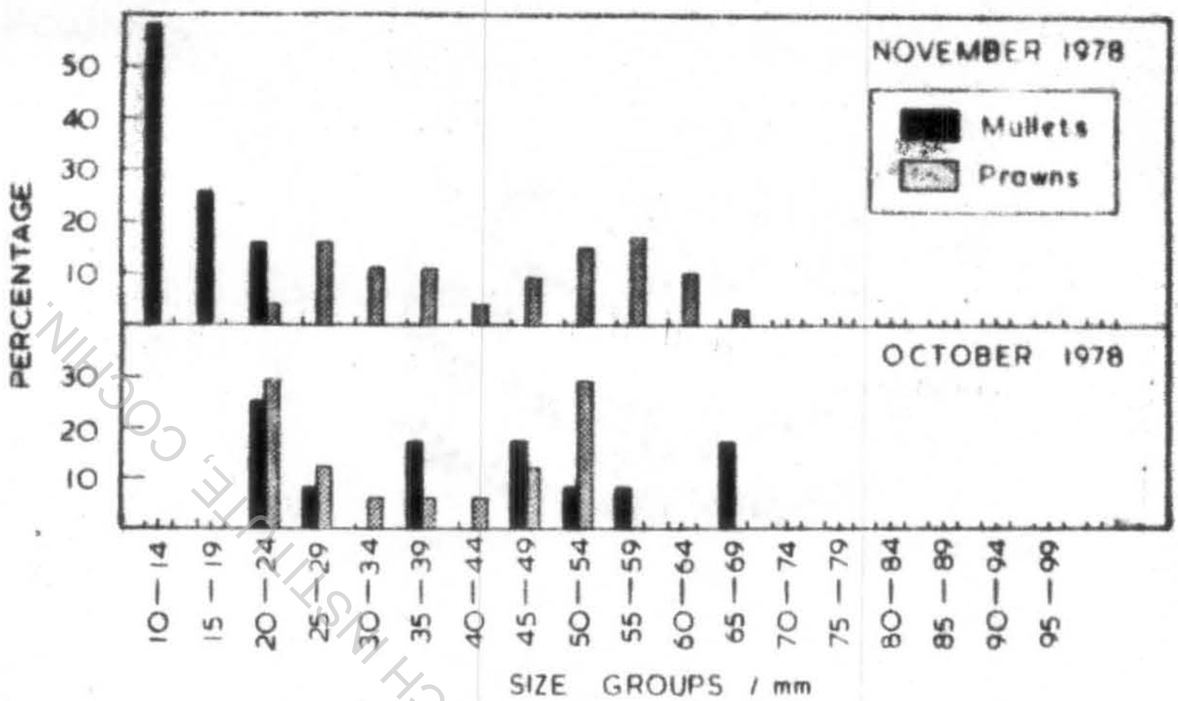


FIG. 25 - C

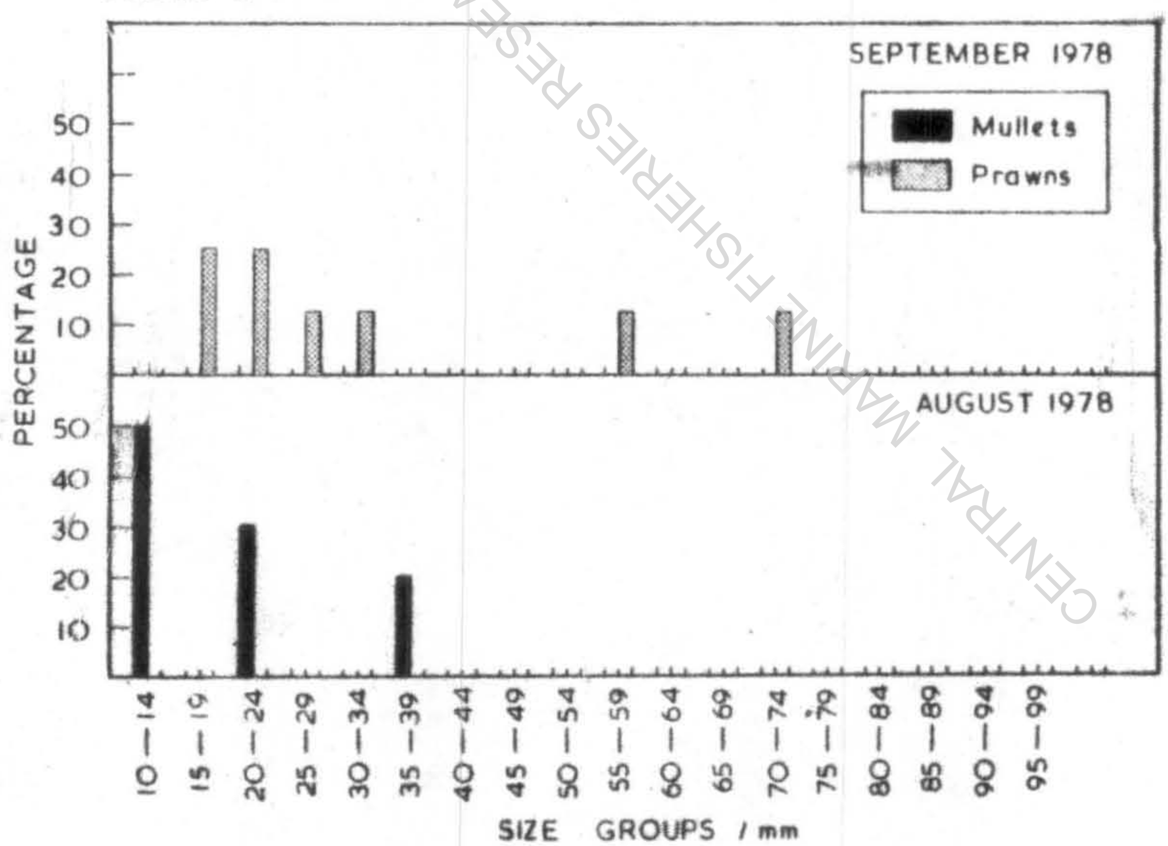


FIG. 25-F

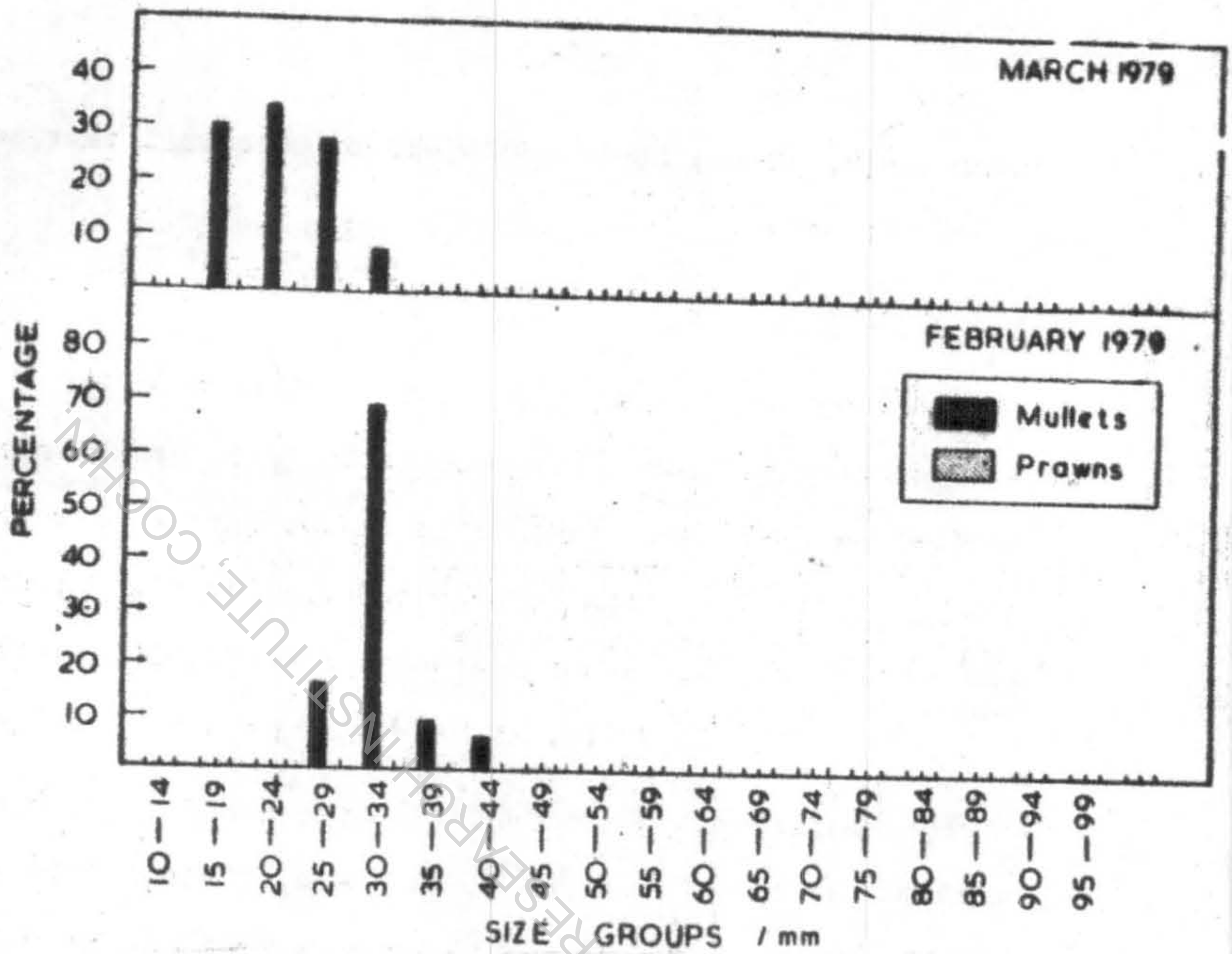
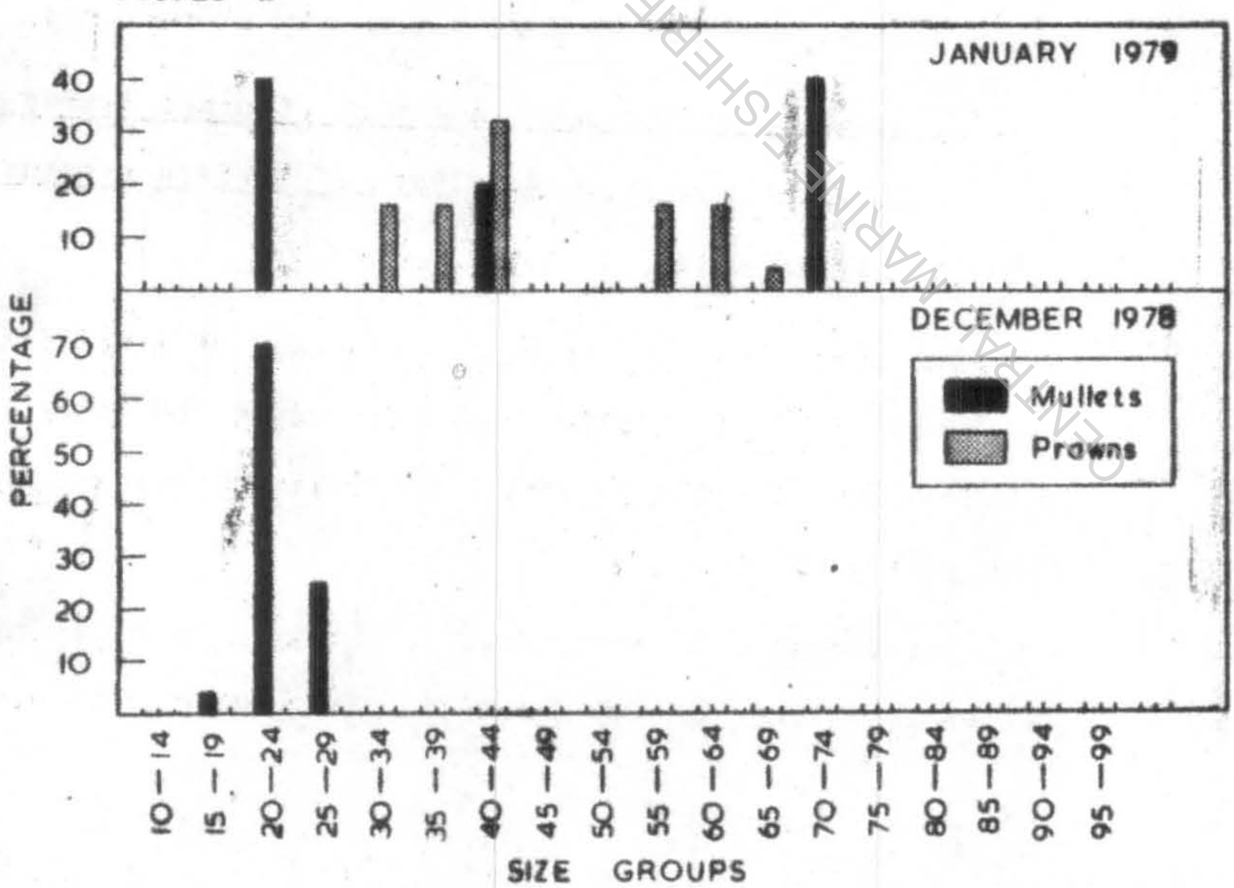


FIG. 25 - E



groups 15-19, 20-24, 30-34 and 35-39 mm were well represented as dominant groups in most of the months.

3.1.2.8 Palar estuary

The length frequency distribution pattern of the mullets showed that the dominance of the size groups ranged from 10-14 & 30-34 mm. These size groups were well represented in most of the months except May. The size groups 35-39 mm and above were not represented uniformly in all the months (Table 16 & Fig. 25 A-F).

The distribution pattern of the fry and fingerlings of prawns showed that the size groups 10-14, 15-19, 20-24 & 25-29 mm were dominant during the months from May to October. Fry measuring above 29 mm were moderately represented.

3.1.3 Assessment of the seed abundance of other fishes and prawns and the stock magnitude of different estuaries

3.1.3.1 Pulicat lake

The percentage occurrence of the seed of other fishes ranged from 9.91 to 73.75. Peak periods of abundance were noted during June and August. This period overlaped the peak period of prawns.

Total number of fish genera recorded by earlier authors ranged from 22 to 25 (Chacko, 1951, 1952; Anantharaman, 1951, Chacko, _et al._, 1953 and Krishnan and Sampath, 1976). In the present survey, fishes belonging to 31 genera are collected and listed below.

Gerres filamentosus Cuvier; _Gerres oblongus_ Cuvier; _Gerres oyena_ (Forskal); _Gobius biocellatus_ Cuvier & Velenciennes; _Gobius hasseltii_ (Bleeker); _Leiognathus splendens_ (Cuvier); _Leiognathus fasciata_ (Lacepede), _Leiognathus bindus_ (Valenciennes); _Mugil cephalus_ Linnaeus; _Liza macrolepis_ (Smith); _Liza parsia_ (Hamilton-Buchanan); _Liza tade_ (Forskal); _Liza waigiensis_ (Quoy and Gaimard); _Valamugil seheli_ (Forskal); _Anchoviella commersonii_ (Lacepede); _Anchoviella indica_ (Van Hasselt); _Nematalosa nasus_ (Bloch); _Belone strongylera_ (Van Hasselt); _Ambassis commersoni_ (Cuvier); _Rhynchorhamphus marginatus_ (Forskal); _Rhynchorhamphus unifasciatus_ (Ranzani); _Allanetta forskali_ (Ruppell)*; _Tachysurus maculatus_ (Thunberg); _Tachysurus caelatus_ (Valenciennes); _Tachysurus thalassinus_ (Ruppell); _Tachysurus dussumieri_ (Cuvier & Valenciennes); _Sphyraena obtusata_ (Cuvier & Valenciennes)*; _Sphyraena barracuda_ (Wallaum)*; _Sphyraena bleekeri_ (Williams); _Plotosus anguillaris_ (Bloch); _Abudefduf sexatilus_ (Quoy and Gaimard)*; _Lutianus johni_ (Bloch); _Lutianus fulviflamma_ (Forskal); _Lutianus russelli_ (Bleeker); _Caranx kalla_ (Cuvier); _Caranx malabaricus_ (Bloch); _Anguilla bicolar_ Day; _Triacanthus brevirostris_ (Schiegel);

Chirocentrus dorab (Forskal); *Elops saurus* (Forskal); *Lethrinus nebulosus* (Forskal); *Tilapia mossambica* (Peters); *Lethrinus variegatus* (Valenciennes); *Sillago sihama* (Forskal); *Etroplus suratensis* (Bloch); *Platycephalus macracanthus* Bleeker; *Siganus oramin* (Bloch & Schneider); *Siganus javus* (Linnaeus); *Chanos chanos* (Forskal); *Thrissocles mystax* (Bloch & Schneider); *Thrissocles malabarica* (Bloch); *Therapon jarbua* (Forskal); *Therapon puta* (Cuvier).

* indicates new species not recorded by earlier authors

Prawns belonging to 3 to 5 species have been recorded by the earlier workers (Subramanyam and Rao, 1970; Manickam and Srinivasagam, 1973; Gopinathan *et al*., 1974 and Gopinathan, 1978). In the present survey the following four species of prawns, besides *Penaeus indicus* Milne-Edwards, were collected namely *Penaeus monodon* Fabricius; *Penaeus semisulcatus* de Haan; *Metapenaeus monoceros* (Fabricius); *Metapenaeus dobsoni* (Miers).

3.1.3.2 Ennore estuary

The occurrence of other fishes was strikingly more in most part of the year and their percentage varied from 9.34 to 91.26. The peak period of abundance was observed during the month of May (91.26%). The pattern of abundance bears an inverse relationship with mullets and prawns.

In earlier studies about 23 genera of fishes have been recorded from this estuary (Chacko, 1956, Chacko and Rajagopal, 1962 and Evangeline and Subbiah, 1969). During the present survey, 36 genera of fishes were reported as given below:

Rhynchorhamphus marginatus (Forskal); Rhynchorhamphus unifasciatus (Ranzani); Therapon jarbua (Forskal); Therapon puta (Cuvier); Anchoviella commersonii (Lacepede); Ambassis commersoni (Cuvier); Mugil cephalus Linnaeus; Liza macrolepis (Smith); Liza parsia (Forskal); Liza tade (Forskal); Liza waigiensis (Quoy and Gaimard); Valamugil seheli (Forskal); Leiognathus splendens (Cuvier); Leiognathus fasciata (Lacepede); Leiognathus bindus (Valenciennes); Gobius biocellatus (Cuvier & Valenciennes)*; Gobius haseltti (Bleeker); Etroplus suratensis (Bloch); Epinephelus tauvina (Forskal)*; Epinephelus malabaricus (Sehneider); Tilapia mossambica (Peters); Triacanthus biaculeatus (Bloch)*; Nematalosa nasus (Bloch)*; Caranx kalla (Cuvier); Caranx malabaricus (Bloch); Allanetta forskali (Ruppell); Gerres oblongus Cuvier; Gerres oyena (Forskal); Gerres filamentosus (Cuvier); Elops saurus (Forskal)*; Megalops cyprinoides (Broussonet); Sardinella albella (Valenciennes); Sardinella fimbriata (Valenciennes); Sillago sihama (Forskal); Chirocentrus dorab (Forskal); Thrissocles mystax (Bloch &

Schneider); *Thrissocles malabarica* (Bloch); *Anguilla bicolar* (McClelland); *Labeo dussumieri* (Valenciennes)*; *Tachysurus thalassinus* (Ruppell); *Tachysurus maculatus* (Thunberg); *Tachysurus dussumieri* (Cuvier & Valenciennes); *Puntius vittatus* Day*; *Cynoglossus cynoglossus* (Hamilton-Buchanan); *Cynoglossus lingua* (Hamilton Buchannan); *Platycephalus macracanthus* Bleeker*; *Chorinemus lysan* (Forskal)*; *Chorinemus tala* Cuvier; *Sphyraena barracuda* (Wallaum)*; *Sphyraena bleekeri* (Williams); *Sphyraena obtusata* (Cuvier & Valenciennes); *Belone stronyglera* (Van Hasselt)*; *Syngnathus fasciatus* (Gray)*; *Lutianus johni*.(Bloch); *Lutianus fulviflamma* (Forskal); *Ophiocephalus striatus* (Bloch)*; *Siganus javus* (Linnaeus); *Siganus oramin* (Bloch & Schneider).

* indicates thirteen more new genera of fishes have been recorded during the present survey

Previous workers have recorded five species of prawns from this estuary (Chacko 1956; Chacko and Rajagopal, 1962 and Evangeline and Subbiah, 1969). In conformity with the earlier report, in the present study also five species of prawns were recorded. They are *Penaeus indicus* Milne-Edwards, *Penaeus monodon* Fabricius; *Penaeus semisulcatus* de Haan; *Metapenaeus monoceros* (Fabricius) and *Acetes indicus* Milne-Edwards.

3.1.3.3 Cooum estuary

Other fishes occurred in abundant numbers during the month of November. Their percentage abundance ranged from 33.33 to 75.33. When compared with the abundance pattern of mullets and prawns, an inverse relationship may be noticed.

The previous workers have recorded 17 to 47 genera of fishes (Abraham, 1962 and Ganapathi, 1964). In the present study only 12 genera of fishes were collected as listed below:

Elops saurus (Forskal); *Megalops cyprinoides* (Broussonet); *Ambassis commersoni* (Cuvier); *Anguilla bicolar* Macclelland; *Mugil cephalus* Linnaeus; *Liza macrolepis* (Smith); *Liza parsia* (Forskal); *Gerres filamentosus* Cuvier; *Platycephalus indicus* (Linnaeus); *Caranx malabaricus* (Bloch); *Gobius haseltti* (Bleeker); *Labeo dussumieri* (Valenciennes); *Allanetta forskali* (Ruppell).

3.1.3.4 Adyar estuary

In the occurrence of other fishes, a close similarity with the pattern of abundance of prawns may be observed. However, a close observation indicates that when prawns were in abundanne, the other fishes declined in the number. The variation in percentage occurrence ranged from 3.33 to 80.22.

A survey of literature indicates that fishes belonging to about 31 genera have been recorded from this estuary (Chacko and Ganapati, 1949; Chacko *et al*., 1954 and Evangeline, 1968). In the present investigation 33 genera of fishes were collected and listed below:

Elops saurus (Forskal); *Platycephalus indicus* (Linnaeus); *Platycephalus serratus* (Cuvier & Valenciennes); *Platycephalus macracanthus* Bleeker; *Ambassis commersoni* (Cuvier); *Epinephelus tauvina* (Forskal); *Mugil cephalus* Linnaeus; *Liza macrolepis* (Smith); *Liza parsia* (Forskal); *Liza waigiensis* (Quoy and Gaimard); *Liza tade* (Forskal); *Valamugil seheli* (Forskal); *Epinephelus malabaricus* (Schneider); *Therapon jarbua* (Forskal); *Therapon puta* (Cuvier); *Chanos chanos* (Forskal); *Gobius biocellatus* (Cuvier & Valenciennes); *Gobius haseltti* (Bleeker); *Leiognathus splendens* (Cuvier); *Leiognathus fasciata* (Lacepede); *Leiognathus bindus* (Valenciennes); *Anchoviella commersonii* (Lacepede); *Anchoviella indica* (Van Hasselt); *Sphyraena bleekeri* (Williams); *Sphyraena barracuda* (Wallaum), *Sardinella fimbriata* (Valenciennes); *Sardinella albella* (Valenciennes); *Chorinemus lysan* (Forskal); *Chirocentrus dorab* (Forskal); *Lutianus johni* (Bloch); *Plotosus angularis* (Bloch); *Chorinemus tala* (Cuvier), *Tilapia mossambica* (Peters); *Anguilla bicolar* McClelland; *Cynoglossus cynoglossus* (Hamilton-Buchanan); *Cynoglossus lingua* (Hamilton-Buchanan); *Puntius vittatus* Day;

Thrissocles mystax (Bloch & Schneider); *Thrissocles malabarica* (Bloch); *Caranx malabricus* (Bloch); *Lethrinus nubulosus* (Forskal); *Megalops cyprinoides* (Broussonet); *Rhynchorhamphus marginatus* (Forskal); *Labeo dussumieri* (Valenciennes); *Allanetta forskali* (Ruppell); *Scorpaena bleekeri* Day; *Tachysurus maculatus* (Thunberg); *Tachysurus dussumieri* (Cuvier & Valenciennes); *Polynemus indicus* Shaw; *Polynemus heptadactylus* (Cuvier & Valenciennes); *Siganus javus* (Linnaeus); *Siganus oramin* (Bloch & Schneider). The species belonging to the genus *Synagris* spp. was not recorded in the present study.

According to the survey conducted by the earlier workers, it is noted that 5 species of prawns have been recorded from this estuary (Evangeline and Sudhakar, 1972 and Bose, *et al.*, 1978). In the present survey the following 4 species of prawns were collected. *Penaeus indicus* Milne-Edwards; *Penaeus monodon* Fabricius; *Penaeus semisulcatus* de Haan and *Metapenaeus monoceros* (Fabricius). The species *Metapenaeus dobsoni* (Miers) was not recorded in the present investigation.

3.1.3.5 Kovalam estuary

The occurrence of fry and fingerlings of other fishes dominated over mullet and prawn seedlings and their percentage abundance varied from 7.33 to 98.85. There were two peak occurrence in their abundance: one during September and another during December.

A total number of about 15 genera of fishes have been reported from this estuary by earlier workers (Evalgeline *et al.*, 1969). In the present survey, fishes belonging to the following 25 genera have been recorded: *Anchoviella commersonii* (Lacepede); *Therapon jarbua* (Forskal); *Therapon puta* (Cuvier); *Mugil cephalus* Linnaeus; *Liza macrolepis* (Smith); *Liza parsia* (Forskal); *Liza tade* (Forskal); *Liza waigiensis* (Quoy and Gaimard); *Valamugil seheli* (Forskal); *Rhynchorhamphus marginatus* (Forskal); *Rhynchorhamphus unifasciatus* (Ranzani); *Elops saurus* (Forskal); *Tachysurus thalassinus* (Ruppell); *Tachysurus dussumieri* (Cuvier & Valenciennes); *Synganthus fasciatus* Gray*; *Gerres filamentosus* Cuvier; *Gerres oyena* (Forskal); *Gerres oblongus* Cuv; *Ambassis commersoni* Cuvier; *Gobius biocellatus* (Cuvier & Valenciennes); *Leiognathus splendens* Cuvier; *Leiognathus fasciata* (Lacepede); *Leiognathus bindus* (Valenciennes); *Megalopes cyprinoides* (Broussonet); *Allanetta forskali* (Ruppell)*; *Tilapia mossambica* (Peters); *Platycephalus indicus* (Linnaeus)*; *Epinephelus tauvina* (Forskal)*; *Epinephelus malabaricus* (Schneider); *Triacanthus brevirostris* Schlegel*; *Etroplus suratensis* (Bloch); *Belone strongylera* (Van Hasselt)*; *Nematalosa nasus* (Bloch)*; *Anguilla bicolar* McClelland*; *Thrissocles mystax* (Bloch & Schneider), *Thrissocles malabarica* (Bloch); *Sillago sihama* (Forskal).

* indicates ten more genera of fishes have been recorded in the present study.

Earlier workers have recorded 4 to 5 species of prawns (Evangeline *et al.*, 1969; Rajendran and Sampath, 1975; Siddharaju and Mekala, 1980 and Siddharaju and Menon, 1980). In the present survey, the following 5 species were collected namely *Penaeus indicus* Milne-Edwards; *Penaeus monodon* Fabricius; *Penaeus semisulcatus* de Haan; *Metapenaeus monoceres* (Fabricius) and *Metapenaeus dobsoni* (Miers).

3.1.3.6 Edayur estuary

The occurrence of fry and fingerlings of other fishes are predominant throughout the period of observation and the percentage abundance ranged from 15.0 to 100.0%. The abundance of other fishes was higher during September (100.0%) and low during the month of June (15.10%). It bears an inverse relationship with mullets and prawns.

There are no previous published reports available regarding the survey of fish and prawn fauna of this estuary. The present survey revealed the occurrence of fishes belonging to 24 genera. They are: *Rhynchorhamphus marginatus* (Forskal); *Rhynchorhamphus unifasciatus* (Ranzani), *Anchoviella commersonii* (Lecepede); *Mugil cephalus* Linnaeus; *Liza macrolepis* (Smith); *Liza parsia* (Forskal); *Liza tade* (Forskal); *Liza waigiensis* (Quoy and Gaimard); *Anguilla bicolar* McClelland; *Triacanthus brevirostris* Schlegel; *Triacanthus biaculeatus* (Bloch); *Ambassis commersoni* (Cuvier); *Gerres filamentosus* (Cuvier);

Gerres oyena (Forskal); Gerres oblongus Cuvier; Leiognathus splendens (Cuvier); Leiognathus fasciata (Lacepede); Leiognathus bindus (Valenciennes); Allanetta forskali (Ruppell); Gobius biocellatus (Cuvier & Valenciennes); Gobius hasseltii (Bleeker); Therapon jarbua (Forskal); Therapon puta (Cuvier); Lutianus johni (Bloch); Platycephalus indicus (Linnaeus); Platycephalus tuberculatus (Cuvier); Tilapia mossambica (Peters); Belone strongylera (Van Hasselt); Nematalosa nasus (Bloch); Sillago sihama (Forskal); Tachysurus thalassinus (Ruppell); Tachysurus dussumieri (Cuvier & Valenciennes); Lethrinus ornatus (Valenciennes). Lethrinus reticulatus (Valenciennes) Megalopes cyprinoides (Brousonet), Elops saurus (Forskal); Epinephelus tauvina (Forskal).

Among prawns, the following four species have been recorded in the present study. Penaeus indicus Milne-Edwards; Penaeus monodon Fabricius; Penaeus semisulcatus de Hann and Metapenaeus monoceros (Fabricius).

3.1.3.7 Sadras estuary

The fry and fingerlings of other fishes occur in abundant numbers during the month of January and appear to predominate the estuary. Their percentage ranged from 13.36 to 93.17. An inverse relationship with mullets and prawns may be observed.

Although about 12 genera of fishes have been recorded by the earlier workers (Evangeline *et al.*, 1969), in the present study, a total number of 24 genera of fishes were collected from this estuary. They are:

Rhynchorhamphus marginatus (Forskal); *Rhynchorhamphus unifasciatus* (Ranzani); *Allanetta forskali* (Ruppell)*; *Gobius biocellatus* (Cuvier & Valenciennes); *Gobius haseltti* (Bleeker); *Mugil cephalus* Linnaeus; *Liza macrolepis* (Smith); *Liza parsia* (Forskal) ; *Anchoviella commersonii* (Lacepede); *Therapon jarbua* (Forskal); *Therapon puta* (Cuvier); *Lethrinus nebulosus* (Forskal)*; *Ambassis commersoni* Cuvier; *Megalops cyprinoides* (Broussonet)*; *Gerres filamentosus* Cuvier; *Gerres oyena* (Forskal); *Triacanthus bruvirostris* (Schlegal)*; *Etroplus suratensis* (Bloch)*; *Leiognathus splendens* (Cuvier); *Leiognathus bindus* (Valenciennes); *Leiognathus fasciata* (Lacepede); *Tilapia mossambica* (Peters); *Tachysurus thalassinus* (Ruppell); *Tachysurus dussumieri* (Cuvier & Valenciennes); *Belone strongylera* (Van Hasselt)*; *Puntius vittatus* Day*; *Sphyraena bleekeri* (Williams)*; *Sphyraena barracuda* (Walbaum); *Caranx kalla* (Cuvier)*; *Caranx malabaricus* (Bloch); *Chaetodon argus* Linnaeus*; *Syngnathus fasciatus* Gray*; *Platycephalus serratus* (Cuvier & Valenciennes)*; *Nematalosa nasus* (Bloch)*.

* indicates the new genera of fishes not recorded by the earlier authors

Among prawns 4 species have been recorded by the previous authors (Evangeline et al., 1969) and the present survey records the occurrence of 5 species as listed below:

Penaeus indicus Milne-Edwards; Penaeus semisulcatus de Hann; Penaeus monodon Fabricius; Metapenaeus monoceros (Fabricius); Metapenaeus dobsoni (Miers) and Acetes indicus Milne-Edwards.

3.1.3.8 Palar estuary

The abundance of fry and fingerlings of other fishes showed a maximum record of 93.55% during April and minimum during July (7.26%). As observed in other estuaries, an inverse relationship between the abundance of other fishes and seedlings of mullets and prawns has been observed.

The fishes belonging to 15 genera were recorded from this estuary by the previous workers (Evangeline et al., 1969). In the present survey 28 genera of fishes have been recorded as reported below:

Anchoviella commersoni (Lacepede); Anguilla bicolar McClelland*; Ambassis commersoni (Cuvier); Allanetta forskali (Ruppell)*; Rhynchorhamphus marginatus (Forskal); Rhynchorhamphus unifasciatus (Ranzani); Leiognathus splendens (Cuvier); Leiognathus fasciata (Lacepede); Leiognathus bindus (Valenciennes); Mugil cephalus Linnaeus; Liza macrolepis (Smith)

Liza parsia (Forskal); *Liza tade* (Forskal); *Liza waigiensis* (Quoy and Gaimard); *Valamugil seheli* (Forskal); *Therapon jarbua* (Forskal); *Therapon puta* (Cuvier); *Gerres filamentosus* Cuvier; *Gerres oblongus* Cuvier; *Gerres biocellatus* Cuvier & Valenciennes*; *Gerres hasseltii* (Bleeker); *Sardinella fimbriata* (Valenciennes)*; *Sardinella albella* (Val); *Syngnathus fasciatus* Gray; *Nematolosa nasus* (Bloch)*; *Platycephalus indicus* (Linnaeus); *Platycephalus serratus* (Cuvier & Valenciennes); *Etroplus suratensis* (Bloch); *Polynemus indicus* Shaw; *Polynemus heptadactylus* (Cuvier & Valenciennes); *Triacanthus biaculeatus* (Bloch)*; *Lutianus johni* (Bloch)*; *Sciaena dussumieri* (Valenciennes)*; *Otolithus argenteus* (Cuvier & Valenciennes); *Elops saurus* (Forskal); *Calyodon fasciatus* (Valenciennes); *Calyodon dussumieri* (Valenciennes); *Chaetodon argus* Linnaeus*; *Chirocentrus dorab* (Forskal)*; *Sillago sihama* (Forskal); *Megalopes cyprinoides* (Broussonet); *Sphyraena barracuda* (Wallaum)*; *Sphyraena bleekeri* (Williams).

* indicates the new genera of fishes not recorded by the earlier authors

Among prawns, 4 species have been recorded by earlier authors (Evalgeline *et al.*, 1969). The present survey revealed the occurrence of 5 species of prawns as listed below; *Penaeus indicus* Milne-Edwards; *Penaeus monodon* Fabricius; *Penaeus semisulcates* de Hann; *Metapenaeus monoceros* (Fabricius) and *Metapenaeus dobsoni* (Miers).

Table 17 Analysis of variance - Mullet *L. macrolepis* (From different estuaries)

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F (Calculated Value)
Between estuaries	7	18405.73	2629.39	3.41
Within estuaries	88	67817.72	770.65	
Total	95	86223.45		

Table value of F for 7, 88 degree of freedom at 5% level is 2.11

Calculated value of F for 7, 88 degree of freedom at 5% level is 3.41

There is significant difference between different estuaries at 5% level

Table 18 Analysis of variance - Prawn P. indicus (From different estuaries)

Source of variation	Degrees of freedom	Sum of Squares	Mean square	F (Calculated Value)
Between estuaries	7	19027.87	2718.26	5.14
Within estuaries	88	46460.78	527.96	
Total	95	65488.65		

Table Value of F for 7, 88 degree of freedom at 5% level is 2.11

Calculated value of F for 7, 88 degree of freedom at 5% level is 5.14

There is significant difference between different estuaries at 5% level

Table 19 Analysis of variance - Other Fishes (From different estuaries)

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F (Calculated Value)
Between estuaries	7	21457.29	3065.32	
				4.35
Within estuaries	88	61907.03	703.48	
Total	95	83364.32		

Table Value of F for 7, 88 degree of freedom at 5% level is 2.11

Calculated Value of F for 7, 88 degree of freedom at 5% level is 4.35

There is significant difference between different estuaries at 5% level

The test of analysis of variance for mullets, *L. macrolepis*, prawns *P. indicus* and other fishes were carried out for the significance of difference between different estuaries. The results are presented in Tables 17 to 19. It may be seen that there is significant difference in the abundance of fry and fingerlings of mullets, prawns and other fishes among different estuaries at 5% level.

3.1.4 Hydrological monitoring of different estuaries around Madras

Hydrological parameters such as temperature, salinity, dissolved oxygen, p^H and water transparency were monitored from April 1978 to March 1979 in the following estuaries : Pulicat, Ennore, Cooum, Adyar, Kovalam, Edayur, Sadras and Palar. The seasonal variation in the above parameters are given in Tables 20-27 and Figs. 26 to 33.

3.1.4.1 Pulicat lake

Temperature: The range of seasonal variation of temperature was between 25.2°C and 32.4°C. The maximum temperature was recorded during the month of June, the value being 32.4°C. Minimum temperature of 25.2°C was observed during January. The annual pattern of temperature is bimodal.

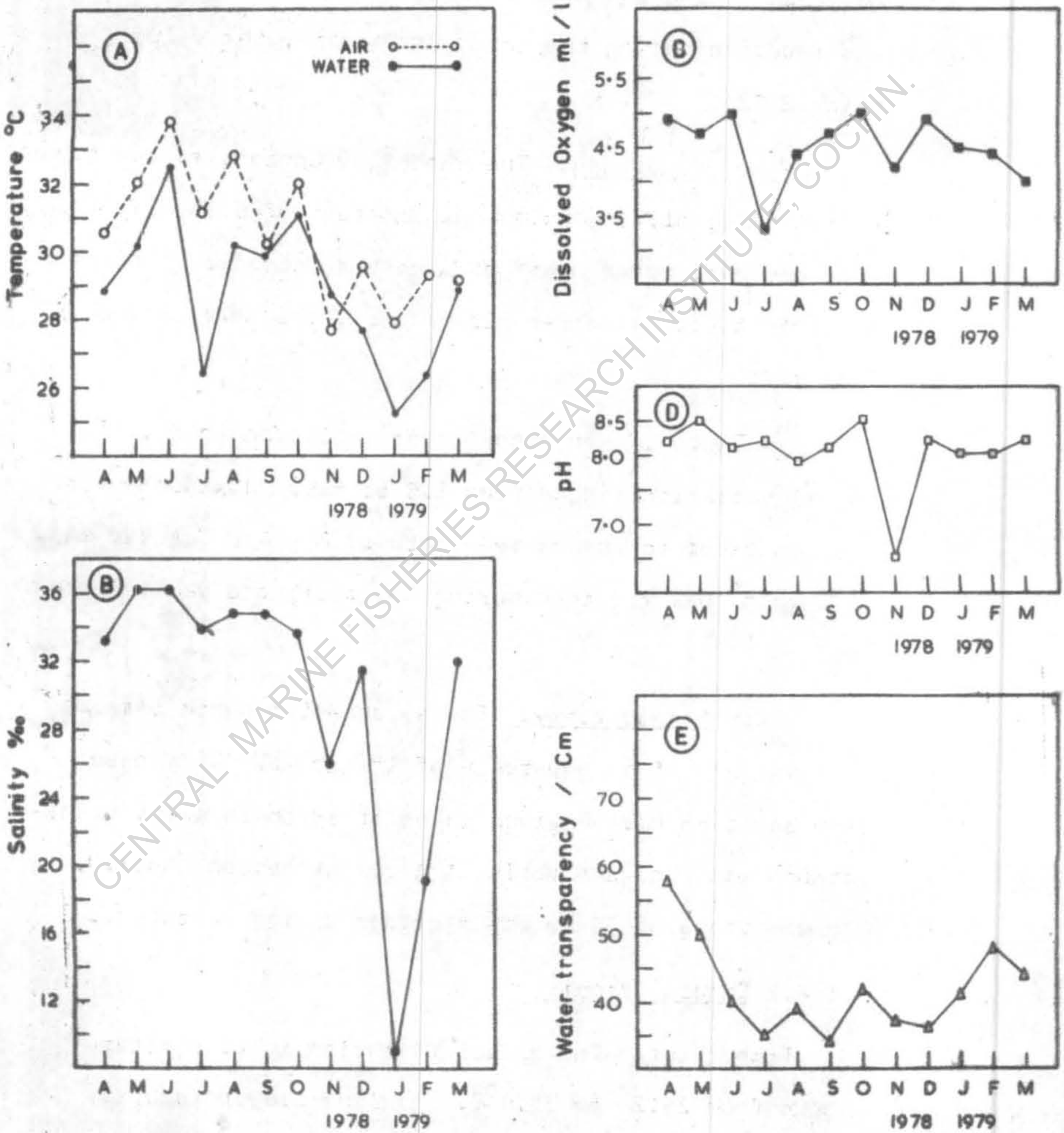
Table 20 Hydrological data collected for the period from April 1978 to March 1979 -Pulicat lake *

Month	Temperature °C Air	Temperature °C Water	salinity ‰	Dissolved oxygen ml/l	pH	Water transparency	Tide	Nature of bar mouth
April	30.5	28.8	33.25	4.91	8.2	58	high	open
May	31.9	30.1	36.21	4.69	8.5	50	low	open
June	33.8	32.4	36.18	5.03	8.1	40	high	open
July	31.1	26.4	33.82	3.35	8.2	35	low	open
August	32.8	30.1	34.81	4.36	7.9	39	high	open
September	30.2	29.8	34.81	4.69	8.1	34	low	open
October	32.0	31.0	33.61	5.03	8.5	42	low	open
November	27.6	28.7	26.06	4.24	6.5	37	high	open
December	29.5	27.6	31.35	4.91	8.2	36	high	open
January	27.8	25.2	8.52	4.47	8.0	41	low	open
February	29.2	26.3	21.13	4.47	8.0	48	low	open
March	29.1	28.8	31.86	4.02	8.2	44	low	open
Overall Mean	30.4	28.7	30.13	4.51	8.0	42.0	-	-
S.D. ±	1.9	2.1	8.10	0.48	0.5	7.0	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Pulicat lake from April 1978 to March 1979.

FIG. 26



Salinity: The annual salinity variation ranged from 8.52‰ to 36.21‰. Maximum salinity of 36.21‰ was recorded during the month of May and minimum salinity was recorded during the month of January, the value being 8.52‰.

Dissolved Oxygen: The annual DO content ranged from 3.35 to 5.03 ml/l. Maximum DO content of 5.03 ml/l was recorded during the month of June and October. Minimum DO content was recorded during July, the value being 3.35 ml/l.

p^H: There was no significant variation in p^H. The annual variation ranged from 6.5 to 8.5. Maximum p^H of 8.5 was recorded during the month of May and October and minimum p^H was recorded during November, the value being 6.5.

Water transparency: The secchi-disc depth was used as a measure of transparency of the water. It ranged from 34 to 58 cm. Maximum value of 58 cm in water transparency was recorded during the summer season (April). Minimum value of 34 cm was recorded during September.

3.1.4.2 Ennore estuary

Temperature: The annual variation in temperature ranged from 25.2° to 30.5°C. Maximum temperature was recorded during the month of October, the value being

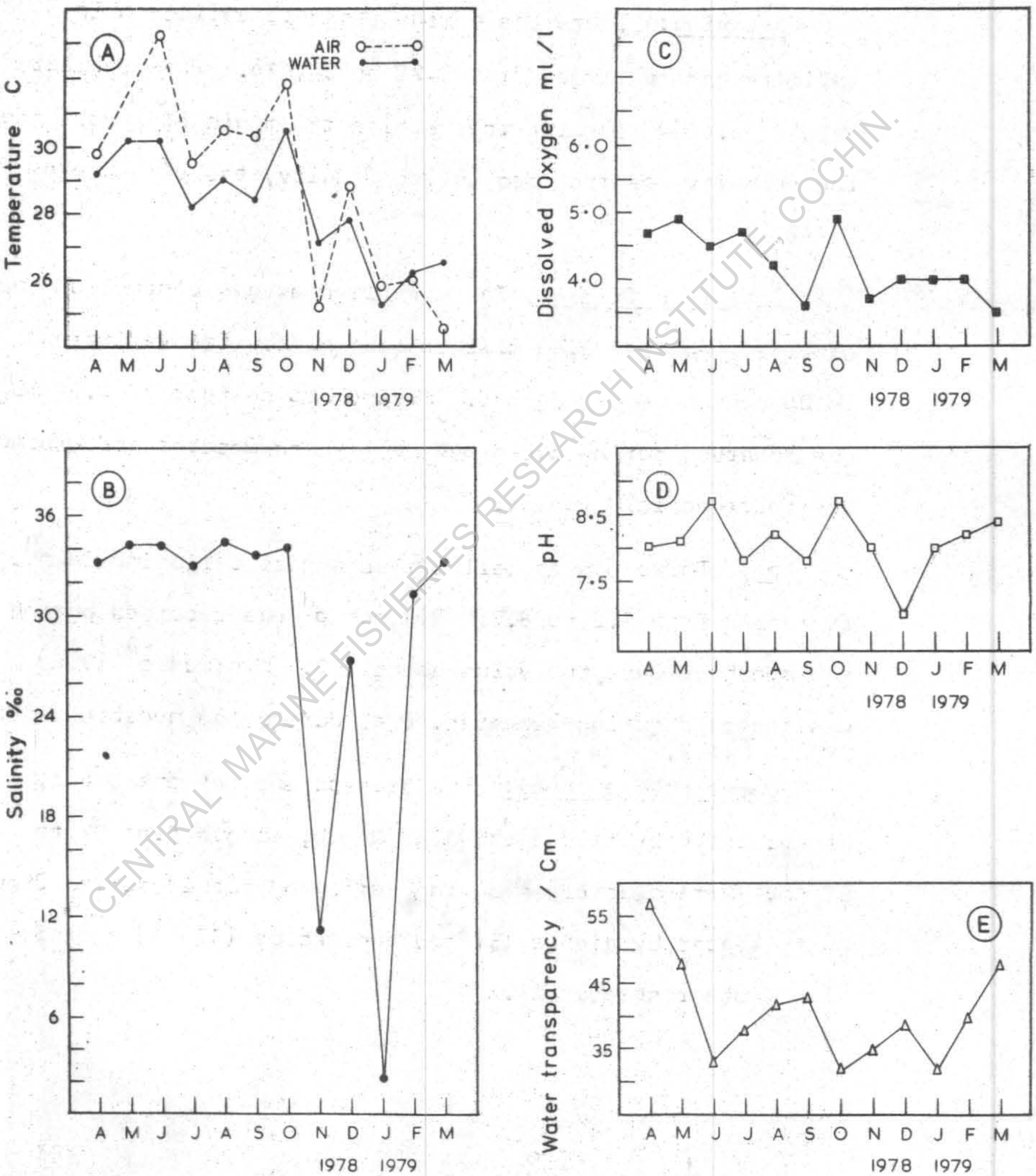
Table 21 Hydrological data collected for the period from April 1978 to March 1979 - Ennore estuary *

Month	Temperature °C		salinity (%.	Dissolved oxygen ml/l	pH	Water trans-parency	Tide	Nature of bar mouth
	Air	Water						
April	29.6	29.2	33.25	4.69	8.0	57	high	open
May	31.7	30.2	34.20	4.91	8.1	48	high	open
June	33.2	30.2	34.20	4.47	8.7	33	high	open
July	29.5	28.2	33.02	4.69	7.8	38	high	open
August	30.5	29.0	34.41	4.24	8.2	42	high	open
September	30.3	28.4	33.64	3.57	7.9	43	high	open
October	31.8	30.5	34.01	4.91	8.7	32	high	open
November	25.2	27.1	11.21	3.68	8.0	35	high	open
December	28.8	27.8	27.28	4.02	7.0	39	low	open
January	25.8	25.2	2.20	4.02	8.0	32	high	open
February	26.0	26.0	31.29	4.02	8.2	40	low	open
March	24.5	26.5	33.24	3.46	8.4	48	high	open
Overall mean	28.9	28.2	28.49	4.22	8.0	40.5	-	-
S.D. ±	2.8	1.7	10.54	0.51	0.4	7.5	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Ennore estuary from April 1978 to March 1979.

FIG. 27



$30.5^{o}C$. Temperature was minimum during January, the value being $25.2^{o}C$. The seasonal pattern of variation is bimodal.

<u>Salinity</u>: There was a wide seasonal variation in salinity and it ranged from 2.20 to 34.41%. Peak salinity value (34.41%.) was recorded during the month of August and low salinity was recorded during January, the value being 2.20%.

<u>Dissolved Oxygen:</u> The dissolved oxygen content of the water ranged from 3.46 ml/l to 4.91 ml/l. The variation in DO content was marginal. Maximum DO content of 4.91 ml/l was observed during the month of May and October and minimum was recorded in November.

<u>p^{H}:</u> There was no well marked annual variation in p^{H}. It ranged from 7.0 to 8.7. Maximum p^{H} was recorded during the month of June, the value being 8.7. Minimum p^{H} (7.0) was recorded during December, i.e. during the monsoon season.

<u>Water transparency:</u> The transparency of the water, as evidenced by the secchi-disc depth, ranged from 32 to 57 cm. Water was clean during April and turbid during January as evidenced by higher (57 cm) and lesser (32 cm) secchi disc depth respectively.

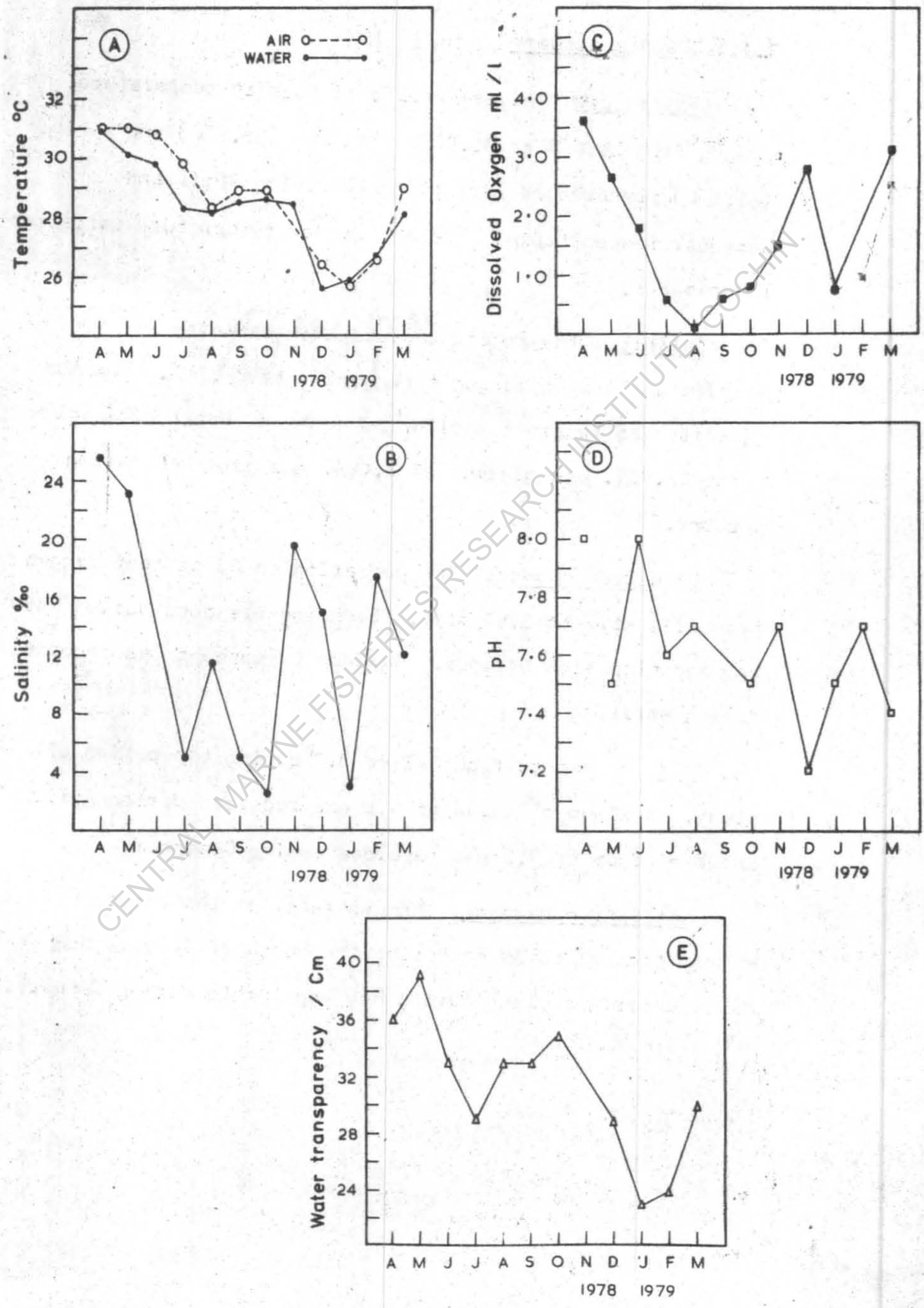
Table 22 Hydrological data collected for the period from April 1978 to March 1979 - Cooum estuary *

Month	Temperature °C Air	Temperature °C Water	Salinity ‰	Dissolved oxygen ml/l	pH	Water transparency	Tide	Nature of bar mouth
April	31.0	30.9	25.76	3.57	8.0	36	High	open
May	31.0	30.1	23.11	2.67	7.5	39	High	open
June	30.8	29.8	14.09	1.77	8.0	33	Low	open
July	29.8	28.3	4.96	0.61	7.6	29	-	closed
August	28.3	28.2	11.74	0.11	7.5	33	-	closed
September	28.9	28.5	4.96	0.61	7.6	33	-	closed
October	28.9	28.6	2.62	0.78	7.5	35	-	closed
November	27.7	28.4	19.65	1.51	7.7	32	Low	open
December	26.4	25.6	15.35	2.79	7.2	29	High	open
January	25.7	25.9	3.38	0.78	7.5	23	Low	open
February	26.6	26.7	17.42	2.00	7.7	24	High	open
March	29.0	28.1	12.39	3.10	7.4	30	High	open
Overall Mean	28.6	28.2	12.95	1.26	7.6	31.3	-	-
S.D. ±	1.8	1.5	7.78	1.19	0.2	4.6	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Cooum estuary from April 1978 to March 1979

FIG. 28



3.1.4.3 Coqum estuary

Temperature: The seasonal variation in temperature ranged from 25.6°C to 30.9°C. Maximum (30.9°C) and minimum (25,6°C) temperature were recorded during April and December respectively. The pattern of temperature variation in unimodal.

Salinity: The annual variation in salinity was significant and it ranged from 2.62%. to 25.76%. Maximum salinity was recorded during the month of April, the value being 25.76%. and minimum of 2.62%. was observed during October.

Dissolved Oxygen: The variation in DO content ranged from 0.11 ml/l to 3.57 ml/l. Sampling was done during both low and high tide periods. Maximum DO content was recorded during April.

p^H: p^H ranged from 7.2 to 8.0 during the period of study. Maximum p^H value of 8.0 was recorded during April and a minimum of 7.2 was recorded during December.

Water transparency: Transparency of the water ranged from 23 to 39 cm during the month of January and May. Water was clean during May and turbid during January.

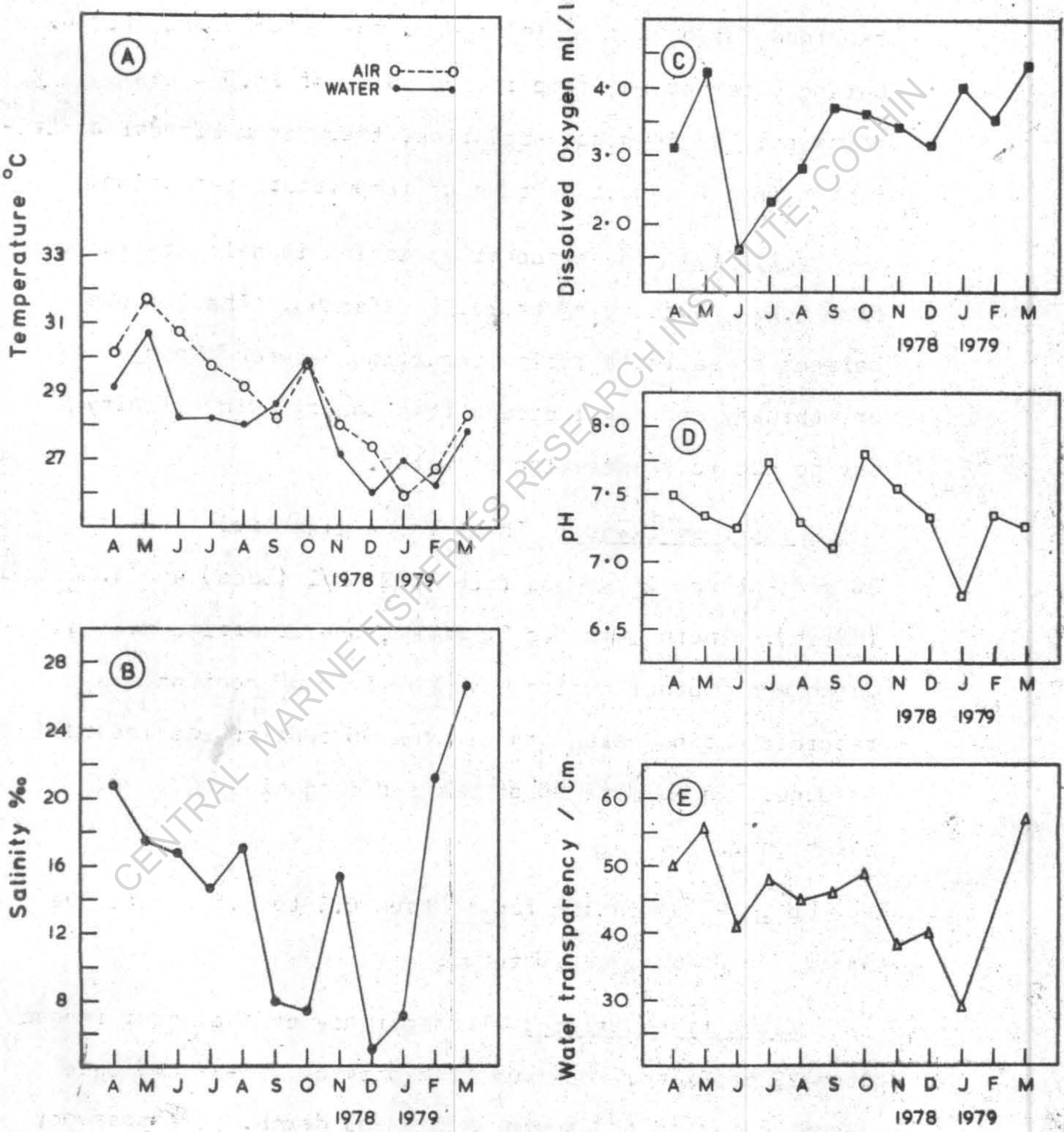
Table 23 Hydrological data collected for the period from April 1978 to March 1979 - Adyar estuary *

Month	Temperature °C Air	Temperature °C Water	Salinity ‰	Dissolved oxygen ml/l	pH	Water trans-parency	Tide	Nature of bar mouth
April	30.1	29.1	20.73	3.12	8.0	50	High	open
May	31.7	30.7	17.41	4.24	7.7	56	High	open
June	30.7	28.2	16.70	1.62	7.5	41	Low	open
July	29.7	28.2	14.63	2.29	8.5	48	Low	open/closed
August	29.2	28.0	17.08	2.84	7.6	45	-	closed
September	28.2	28.6	7.88	3.68	7.2	46	-	closed
October	29.7	29.9	7.34	3.69	8.6	49	Low	open
November	28.0	27.1	15.07	3.40	8.1	38	High	open
December	27.4	26.0	5.01	3.14	7.7	40	High	open
January	25.9	27.0	7.14	4.02	6.5	29	Low	open
February	26.7	26.2	21.03	3.57	7.7	44	High	open
March	28.3	27.8	26.51	4.30	7.5	57	High	open
Overall Mean	28.5	28.0	14.70	3.36	7.7	44.7	-	-
S.D. ±	2.0	1.4	6.65	0.74	0.5	7.1	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Adyar estuary from April 1978 to March 1979

FIG. 29



3.1.4.4 Adyar estuary

Temperature: The annual fluctuation in temperature ranged from 26.0 to 30.7 ^{o}C. Maximum temperature was recorded during the month of May, the value being 30.7 ^{o}C. During December low temperature value of 26.0 ^{o}C was observed. As in other estuaries, there is a bimodal distribution in the annual pattern of temperature variation.

Salinity: The seasonal variation in salinity ranged from 5.01%. (December) to 26.5‰ (March). The two peak periods of salinity regime occurring between the months of February and May indicate that the rise in salinity may be due to evaporation of water.

Dissolved oxygen: There was a wide variation in DO content and it ranged from 1.62 ml/l (June) and 4.30 ml/l (March). There were two DO peaks, one occurring during March and another during May. Maximum DO content was recorded during March and minimum DO content was recorded in June. In general DO of water during high tide period was higher.

p^H: p^H variation ranged from 6.5 to 8.6 during the months of January and October.

Water transparency: Transparency of the water ranged from 29 to 57 cm. Maximum transparency (56-57 cm) were observed during the months of May and March. Transparency was low during January, the value being 29 cm.

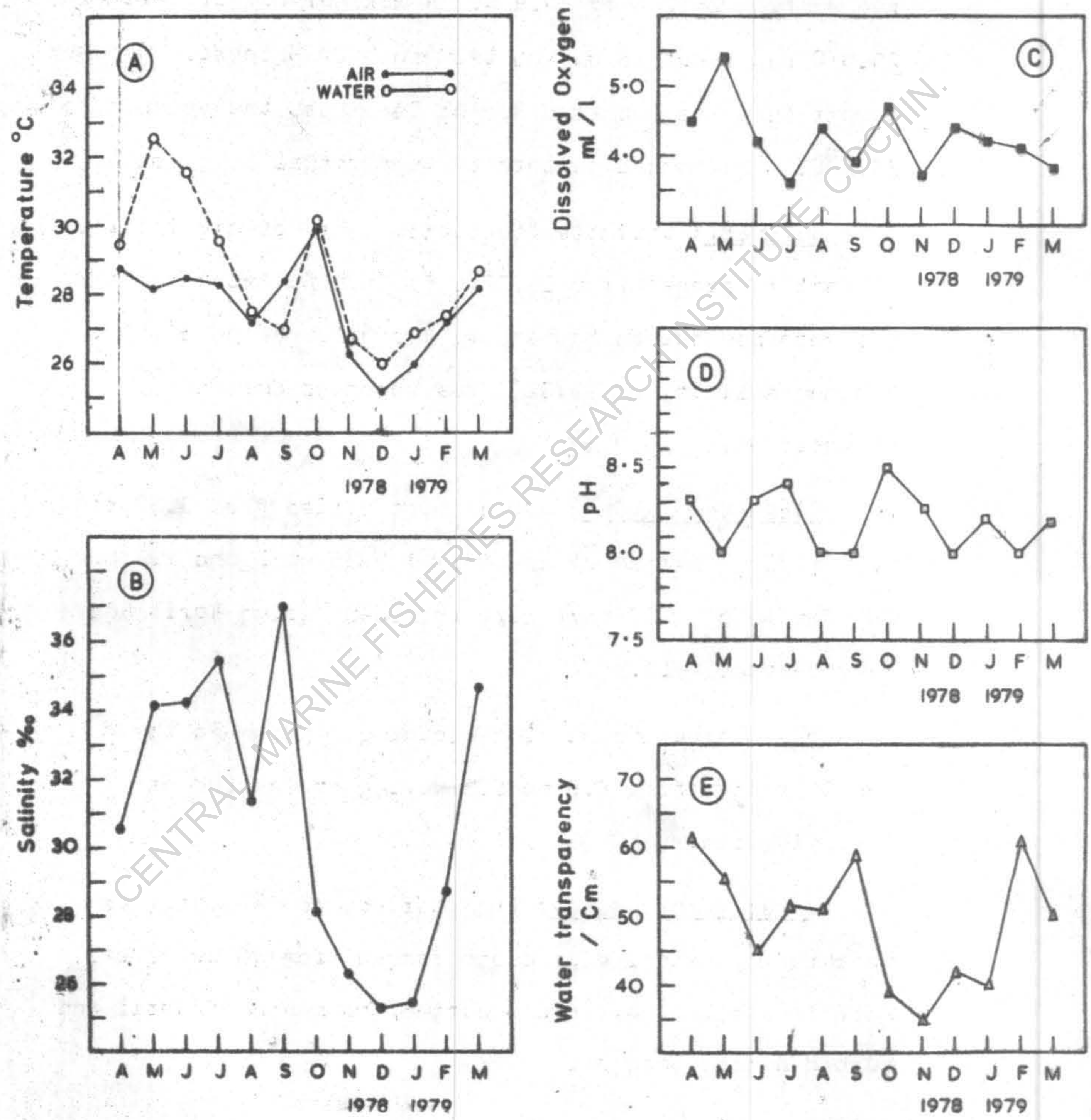
Table 24 Hydrological data collected for the period from April 1978 to March 1979 - Kovalam estuary *

Month	Temperature °C Air	Temperature °C Water	Salinity ‰	Dissolved oxygen ml/l	pH	Water trans-parency	Tide	Nature of bar mouth
April	29.5	28.8	30.51	4.47	8.3	63	High	open
May	32.6	28.2	34.18	5.36	8.0	56	High	open
June	31.6	28.5	34.20	4.24	8.3	45	-	closed
July	29.6	28.4	35.41	3.57	8.4	53	-	closed
August	27.5	27.2	31.29	4.36	8.0	52	-	closed
September	27.0	28.4	36.96	3.90	8.0	58	-	closed
October	30.2	29.9	28.09	4.69	8.5	38	-	closed
November	26.8	26.3	26.26	3.69	8.3	35	Low	open
December	26.0	25.2	25.32	4.36	8.0	44	High	open
January	26.9	26.0	25.52	4.24	8.2	40	Low	open
February	27.4	27.2	28.75	4.13	8.0	62	High	open
March	28.7	28.2	34.61	3.80	8.2	50	High	open
Overall Mean	28.6	27.6	30.92	4.23	8.2	49.6	-	-
S.D. ±	2.0	1.3	4.12	0.48	0.2	9.3	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Kovalam estuary from April 1978 to March 1979

FIG. 30



3.1.4.5 Kovalam estuary

Temperature: The seasonal variation in temperature ranged from 25.2 ^{0}C to 29.9 ^{0}C. A maximum temperature of 29.9 ^{0}C was recorded during the month of October. Minimum temperature was recorded during December, the value being 25.2 ^{0}C. The annual pattern of temperature is bimodal.

Salinity: Salinity fluctuation was not significant in that it ranged from 25.32%. to 36.96%. Peak salinity was recorded during September, the value being 36.96%. Minimum salinity of 25.32%. was recorded during the month of December.

Dissolved Oxygen: DO content varied from 3.57 to 5.36 ml/l. Maximum DO content of 5.36 ml/l and minimum DO content of 3.57 ml/l were recorded during April and July respectively.

p^H: There was no significant variation in the p^H and it ranged from 8.0 to 8.5 during the period of investigation.

Water transparency: Transparency of the water as measured by secchi-disc depth ranged from 40 to 63 cm. Water was relatively clean during the month of April and turbid during January.

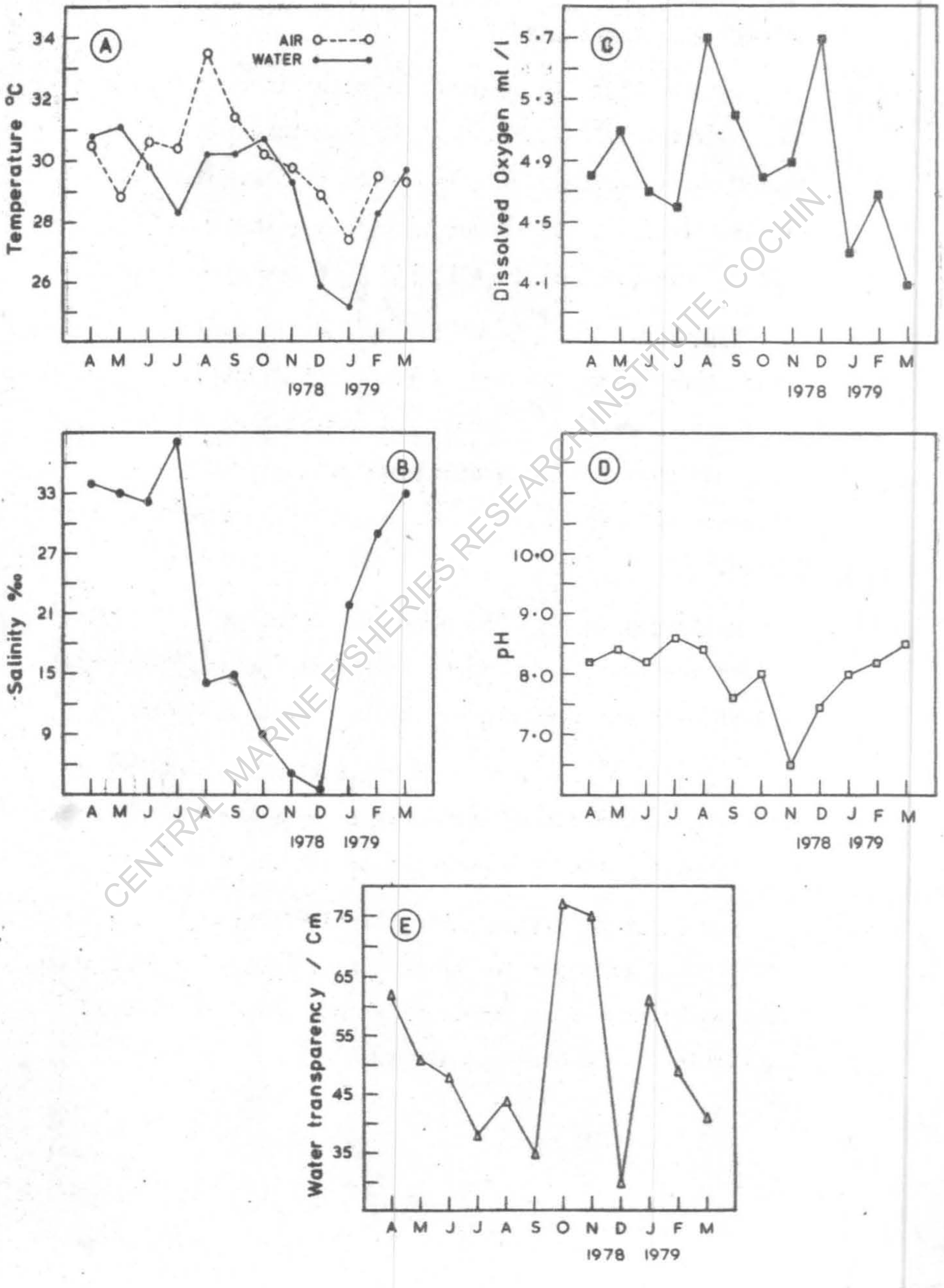
Table 25 Hydrological data collected for the period from April 1978 to March 1979 - Edayur estuary *

Month	Temperature °C Air	Temperature °C Water	Salinity ‰	Dissolved oxygen ml/l	pH	Water transparency	Tide	Nature of bar mouth
April	30.5	30.8	34.30	4.58	8.2	62	High	open
May	28.8	31.1	33.46	4.91	8.4	51	High	open
June	30.6	29.8	32.88	4.47	8.2	48	High	open
July	38.4	28.3	38.29	4.36	8.6	38	-	closed
August	33.5	30.2	14.29	5.47	8.4	44	-	closed
September	31.4	30.2	15.27	5.03	7.6	35	-	closed
October	30.2	30.7	8.77	4.63	8.0	77	-	closed
November	29.8	29.3	4.70	4.69	6.5	75	-	closed
December	28.9	25.9	3.48	5.47	7.5	30	-	closed
January	27.4	25.2	22.16	4.13	8.0	61	Low	open
February	29.5	28.3	29.14	4.47	8.2	49	High	open
March	29.3	29.7	33.44	3.90	8.5	41	Low	open
Overall Mean	30.0	29.5	22.50	4.67	8.0	50.9	-	-
S.D. ±	1.5	1.7	12.63	0.48	0.5	15.0	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Edayur estuary from April 1978 to March 1979.

FIG. 31



3.1.4.6 Edayur estuary

Temperature: The annual variation in temperature ranged from 25.2°C to 31.1°C. Maximum temperature of 31.1°C was recorded during the month of May. Minimum temperature was recorded during January, the value being 25.2°C. Bimodal nature of temperature was observed.

Salinity: The seasonal fluctuation in salinity ranged from 3.58‰ (December) to 38.29‰ (July). As in the other estuaries, the peak salinity during April overlaped the high temperature period suggesting the influence of evaporation in elevating the salinity of the medium.

Dissolved Oxygen: The peak DO content of 5.47 ml/l was recorded during the month of August and low DO content of 3.90 ml/l was recorded during the month of March.

p^H: The p^H was ranged from 6.5 to 8.6. Peak p^H of 8.6 was recorded during the month of July and low p^H of 6.5 was recorded during the month of November.

Water transparency: The secchi-disc depth used as a measure of transparency of the water indicated that clean water occurred during October (77 cm), while the water was turbid during December (30 cm).

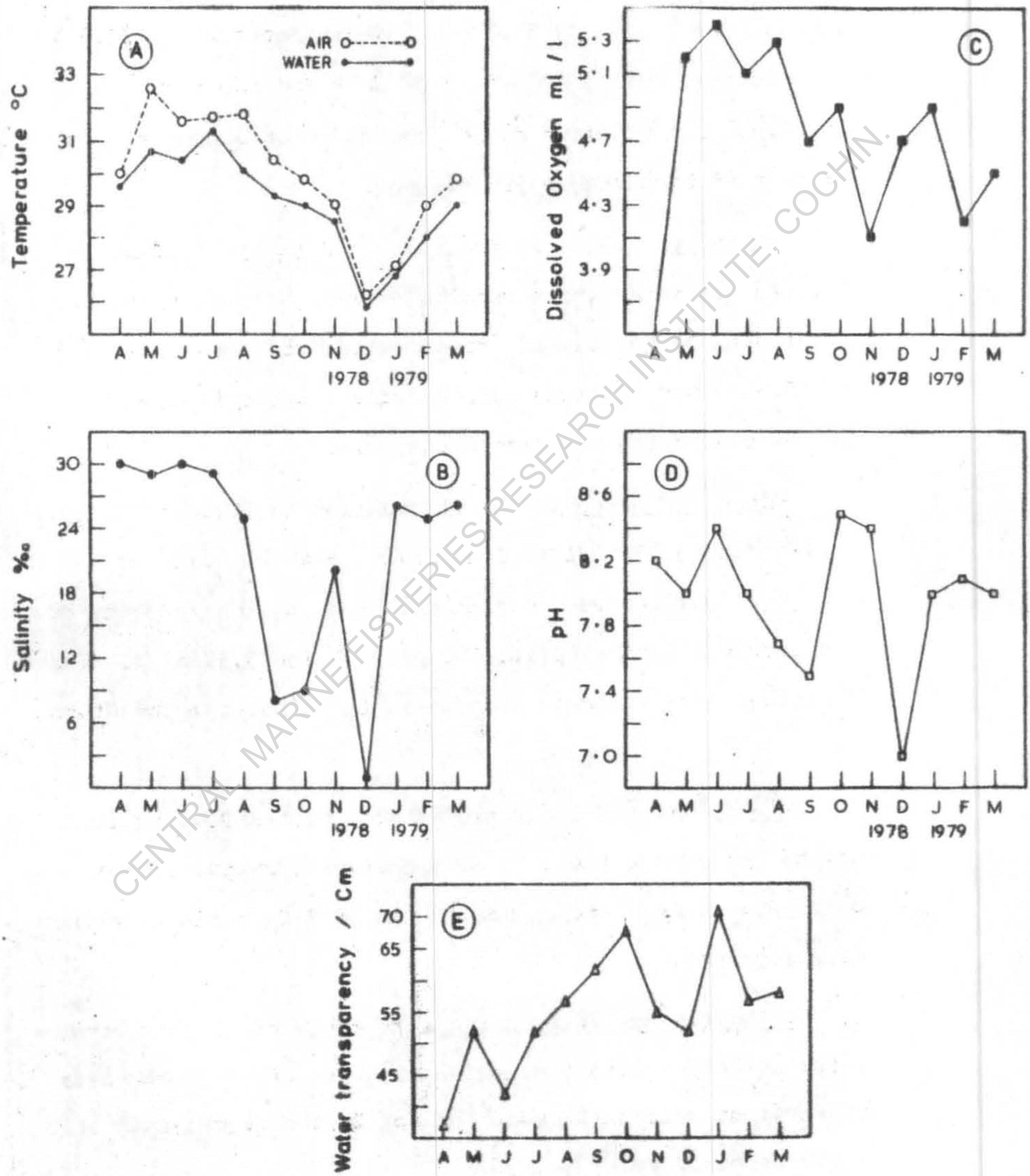
Table 26 Hydrological data collected for the period from April 1978 to March 1979 - Sadras estuary *

Month	Temperature °C Air	Temperature °C Water	Salinity ‰	Dissolved oxygen ml/l	pH	Water transparency	Tide	Nature of bar mouth
April	30.0	29.6	30.71	3.57	8.2	37	-	closed
May	32.6	30.7	29.30	5.25	8.0	52	-	closed
June	31.6	30.4	30.56	5.36	8.4	42	-	closed
July	31.7	31.3	29.40	5.14	8.0	52	-	closed
August	31.8	30.1	25.47	5.25	7.7	57	-	closed
September	30.4	29.3	7.84	4.69	7.5	62	-	closed
October	29.8	29.0	8.62	4.91	8.5	68	-	closed
November	29.0	28.5	19.75	4.13	8.4	55	High	open
December	26.2	25.8	1.04	4.69	7.0	52	High	open
January	27.1	26.8	26.31	4.91	8.0	71	High	open
February	29.0	28.0	25.13	4.24	8.1	57	-	closed
March	29.8	29.0	25.97	4.47	8.0	63	-	closed
Overall Mean	29.9	29.0	21.67	4.71	7.9	54.8	-	-
S.D. ±	1.9	1.5	10.16	0.53	0.4	10.1	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Sadras estuary from April 1978 to March 1979

FIG. 32



3.1.4.7 Sadras estuary

Temperature: The annual variation in temperature ranged from 25.8°C to 31.3°C. Peak temperature of 31.3°C was recorded during the month of July and low temperature of 25.8°C was recorded during the month of December. The pattern of temperature is unimodal.

Salinity: Wide fluctuations in salinity (1.04%. to 30.56%.) was noted which recalls similar variation in the water body of Ennore and Edayur estuaries. Peak salinity of 30.56%. was recorded during April. Low salinity of 1.04%. was observed during December.

Dissolved Oxygen: The fluctuation in DO content varied from 3.57 ml/l to 5.36 ml/l. Peak DO value of 5.36 ml/l was recorded during the month of June and low DO was recorded during April, the value being 3.57 ml/l. The DO values were found to be relatively higher throughout the year.

p^H: p^H of the water ranged from 7.0 to 8.4 and it may be noted that there is no significant pattern. Peak p^H of 8.4 during October and low p^H of 7.0 during December were recorded.

Water transparency: During the month of October, the water was clear with a secchi-disc depth of 68 cm and less transparent during the month of April, the secchi-disc depth being 37 cm.

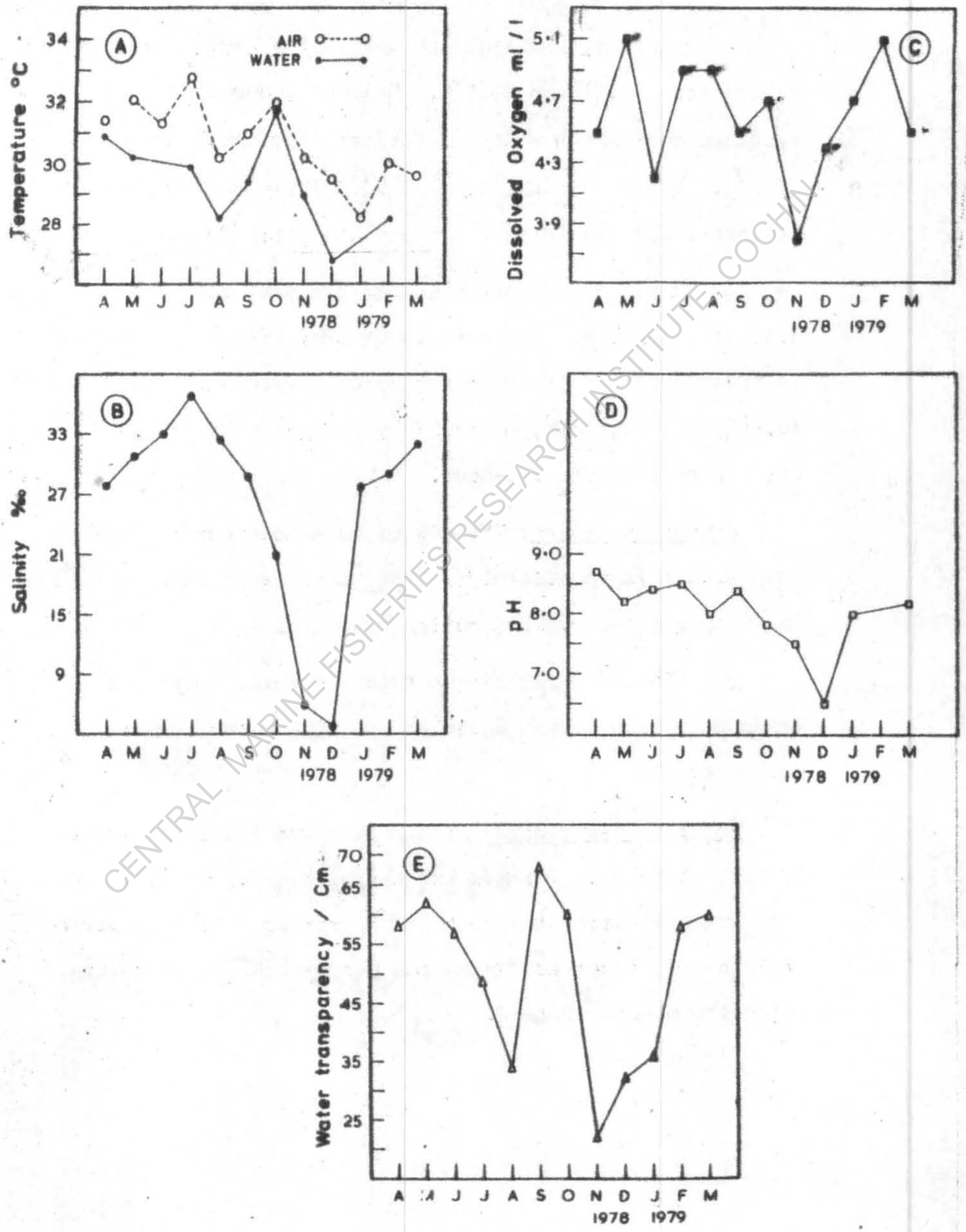
Table 27 Hydrological data collected for the period from April 1978 to March 1979 - Palar estuary *

Month	Temperature °C		Salinity ‰	Dissolved oxygen ml/l	pH	Water transparency	Tide	Nature of bar mouth
	Air	Water						
April	31.4	30.9	27.97	4.47	8.7	58	Low	open
May	32.1	30.2	31.53	4.14	8.2	62	High	open
June	31.3	30.1	32.69	4.24	8.4	57	Low	open
July	32.8	29.9	36.94	4.91	8.5	49	High	open
August	30.2	28.2	32.66	4.91	8.0	34	Low	open
September	31.0	29.4	29.45	4.47	8.4	68	High	open
October	32.0	31.7	20.81	4.69	7.8	60	High	open
November	30.2	29.0	6.33	3.80	7.5	22	Low	open
December	29.5	26.8	3.48	4.36	6.5	32	Low	open
January	28.2	27.5	27.89	4.70	8.0	36	High	open
February	30.0	28.2	28.95	5.14	8.1	58	High	open
March	29.6	29.4	31.86	4.47	8.2	60	High	open
Overall Mean	30.6	29.2	25.88	4.60	8.0	49.6	-	-
S.D. ±	1.3	1.4	10.84	0.38	0.5	14.7	-	-

* Mean of two observations

Seasonal fluctuations in (A) Temperature (B) Salinity (C) Dissolved oxygen (D) pH and (E) Water transparency in Palar estuary from April 1978 to March 1979

FIG. 33



3.1.4.8 Palar estuary

Temperature: The seasonal variation in temperature ranged from 26.8°C to 31.7°C. Maximum temperature was recorded during the month of October, the value being 31.7°C. Minimum temperature of 26.8°C was observed during December. The pattern of temperature variation in bimodal.

Salinity: The fluctuation in salinity ranged from 3.48 to 36.96‰. and the pattern of variation was similar to those observed in other estuaries. Peak salinity of 36.96‰. was recorded, during July and low salinity of 3.48‰. was recorded during December.

Dissolved oxygen: The dissolved oxygen content varied from 3.80 ml/l to 5.14 ml/l. The DO content was high during February and May and low during November.

p^H: The p^H value ranged from 6.5 to 8.7 with a low value occurring during December and high value occurring during April.

Water transparency: Transparency of the water ranged from 22 to 68 cm. The maximum secchi-disc depth of 68 cm was recorded during the month of September. Minimum depth of 22 cm was recorded during the month of November which being the monsoon period.

Table 28 Analysis of variance - Temperature (From different estuaries)

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F (Calculated value)
Between estuaries	7	89.13	12.73	0.45
Within estuaries	88	2450.04	27.84	
Total	95	2539.17		

Table Value of F for 7, 88 degree of freedom at 5% level is 2.11

Calculated Value of F for 7, 88 degree of freedom at 5% level is 0.45

There is no significant difference between different estuaries at 5% level.

Table 29 Analysis of variance - Salinity (From different estuaries)

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F (Calculated Value)
Between estuaries	7	3869.12	552.73	
				6.57
Within estuaries	88	7394.28	84.02	
Total	95	11263.40		

Table Value of F for 7, 88 degree of freedom at 5% level is 2.11

Calculated value of F for 7, 88 degree of freedom at 5% level is 6.57

There is significant difference between different estuaries at 5% level

Table 30 Analysis of variance - Dissolved Oxygen (From different estuaries)

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F (Calculated Value)
Between estuaries	7	110.53	15.79	
				10.52
Within estuaries	88	132.40	1.50	
Total	95	242.93		

Table Value of F for 7, 88 degree of freedom at 5% level is 2.11

Calculated Value of F for 7, 88 degree of freedom at 5% level is 10.52

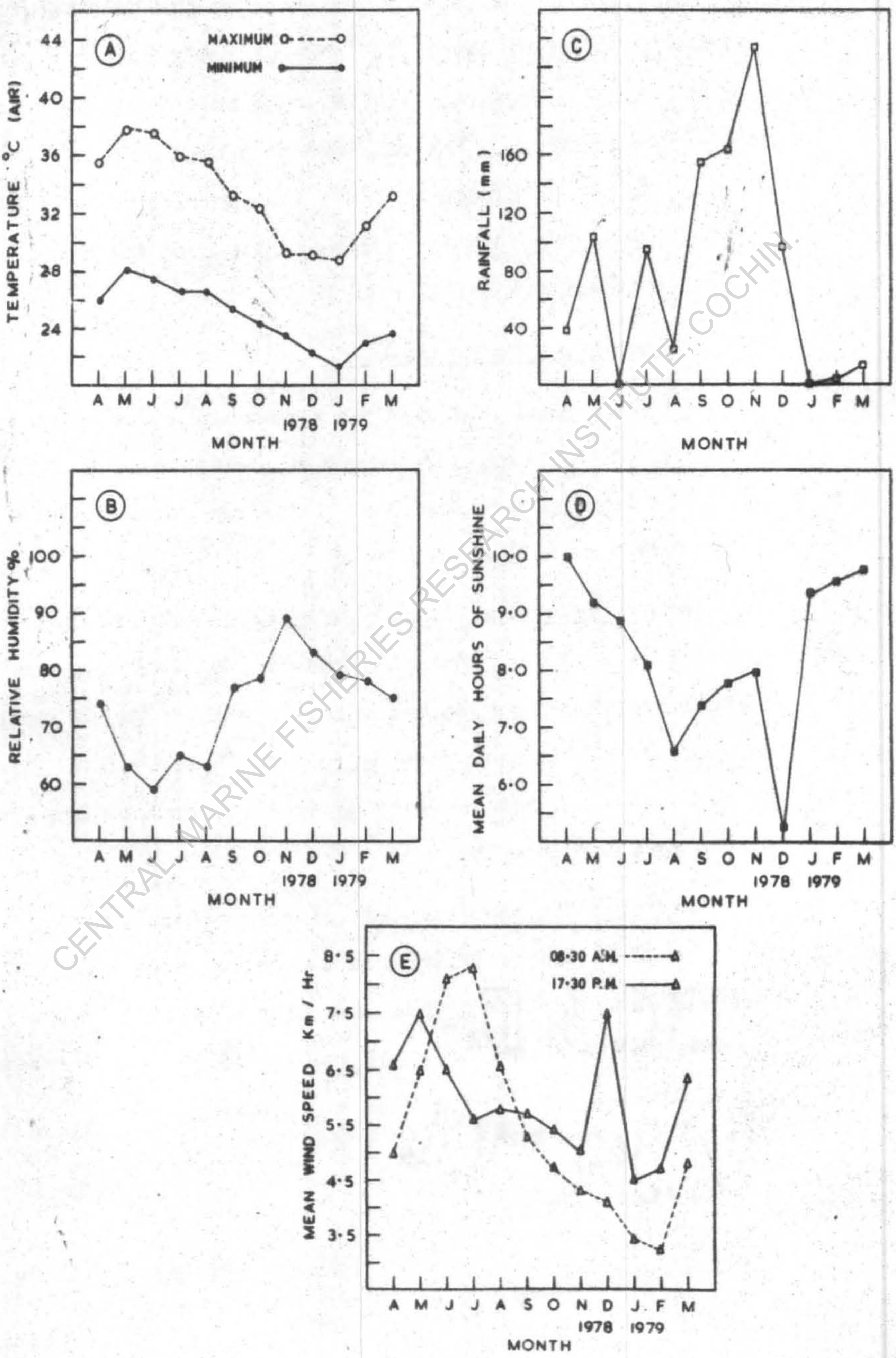
There is significant difference between different estuaries at 5% level.

Table 33 Meteorological data for the period from April 1978 to March 1979 - Madras

Month	Mean air temperature °C Minimum	Mean air temperature °C Maximum	Percentage of relative humidity	Total rain fall (mm)	Average daily hours of sunshine	Mean wind speed km/h 0830 hrs	Mean wind speed km/h 1730 hrs
April	26.0	35.6	73.80	39.3	9.99	05.0	06.6
May	28.2	37.9	62.83	104.3	9.17	06.5	07.5
June	27.6	37.6	58.90	00.0	8.93	08.1	06.5
July	26.7	36.0	65.22	95.0	8.22	08.3	05.6
August	26.7	35.7	63.19	24.8	6.58	06.6	05.8
September	25.4	33.3	77.50	154.7	7.36	05.3	05.7
October	24.4	32.4	78.09	164.1	7.76	04.7	05.4
November	23.5	29.3	89.06	635.5	8.02	04.3	05.0
December	22.3	29.2	82.51	95.7	5.25	04.1	07.5
January	21.3	28.8	78.90	00.0	9.37	03.4	04.5
February	23.0	31.1	77.85	02.4	9.65	03.2	03.2
March	23.7	33.2	75.26	13.0	9.82	04.8	06.3

Seasonal variations in (A) Air temperature (B) Relative humidity (C) Rainfall (D) Daily hours of sunshine and (E) Wind speed in Madras during the mullet, prawn and other fish seed resources survey period from April 1978 to March 1979

FIG. 34



The test of analysis of variance for the temperature, salinity, dissolved oxygen, p^H and water transparency were carried out to assess the significance of difference between different estuaries. The results are presented in Table 28 to 32. It may be seen that there is significant difference in the various hydrological parameters except temperature among different estuaries at 5% level.

3.1.5 <u>Meteorological observations</u>

Meteorological data such as temperature, humidity, rainfall, sunshine and wind speed of coastal Madras were collected for the survey period i.e. from April 1978 to March 1979 (Table 33 & Fig. 34).

<u>Temperature:</u> The maximum atmospheric temperature ranged from 28.8°C to 27.9°C. Maximum among the maximum temperature range was recorded in the month of May. Similarly, the minimum temperature ranged from 21.3°C to 28.2°C. Maximum temperature among the range of minimum temperature was observed in the month of January.

<u>Humidity</u>: The seasonal variation in relative humidity varied from 58.90% to 89.06% for the period from April 1978-March 1979. Maximum humidity was observed during November, the value being 89.06% and a minimum of 58.90% was recorded during June.

Rain fall: The annual variation in rainfall ranged from 2.4 mm to 635.5 mm. Maximum rainfall was recorded during the month of November, the value being 635.5 mm. Minimum rainfall of 2.4 mm was recorded during February. The north-east monsoon (October-December) is the main rain bearing season. South-West monsoon (June-August) is relatively less intense than the North-East monsoon.

Sunshine: The average daily hours of sunshine ranged from 5.25 to 9.99 hr. Maximum daily hours of sunshine was observed during the month of April, the value being 9.99 hr. Minimum daily hours of sunshine (5.25) was recorded during December.

Wind speed: The wind speed ranged from 0.3 km/h to 7.5 km/h. Maximum wind speed was recorded during the month of May and December. Minimum wind speed was recorded during February, the value being 0.3 km/h.

3.2.0 Bioassay/aquaculture experiments under field conditions to evaluate the water quality from mortality and growth rate of mullet *Liza macrolepis* (Smith) in Adyar estuary, Madras

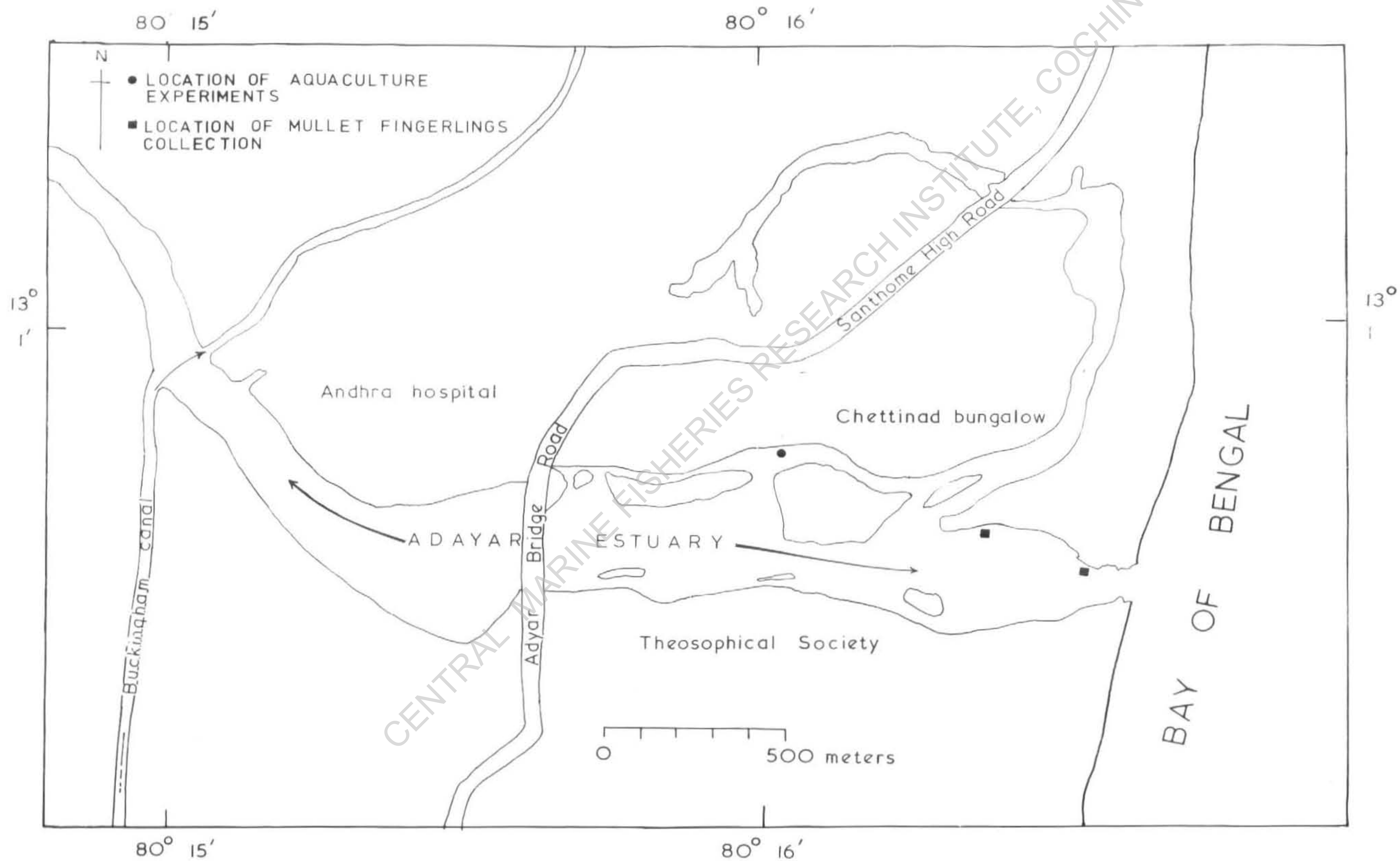
Since fish forms an important source of human food, the production of fish flesh under different natural and cultural conditions is of considerable economic value (Brown, 1957; Collins and Delmendo, 1976 and Huguenin and Ansuini, 1978). In recent years, there is a growing interest throughout the world in fish production by cage culture partly because cage culture offers certain advantages. It permits close observation of the feeding efficiency and general health of the fish and ensures a complete harvest and manipulation of the harvest to fit market requirements (Schmittou, 1969; Buck <u>et al</u>., 1971; Collins, 1971; Kilambi <u>et al</u>., 1977 and Boydstun and Hopelain, 1977).

Cultivation of marine and estuarine organisms in aquatic environment has been used as a means for assessing the quality of the water (Braarud, 1961). Further, the relative growth rate of fishes also forms a tool for environmental evaluation of aquatic habitats (Gunning and LaNasa, 1973 and Edwards and Edelsten, 1976). In order to assess the environmental impact as a consequence of pollution load on the colonization, survival, adaptability, tolerance range and growth rate of the cultivable mullet, <u>Liza macrolepis</u> (Smith), it is felt of interest to undertake a few exploratory aquaculture experiments in Adyar estuary, Madras (13° 1'N and 80° 17' N) by culturing fishes in polluted water.

FIG. 35

MAP SHOWING A PORTION OF ADYAR ESTUARY MADRAS

LOCATION OF MULLET FINGERLINGS COLLECTION AREAS AND AQUACULTURE EXPERIMENTS



Aquaculture experiments were conducted in the Adyar estuary near "Chettinad Bungalow" located at a distance of about 0.8 kms from the bar mouth of the estuary (Fig. 35). Wooden cages of the size 2 x 2 x 1 m and 2 x 1 x 1 m, were used in the present study. The length and weight of the fingerlings ranged from 80-85 mm and 5.0 to 5.5 gm respectively (vide Material & Methods).

In view of the pollution load, it was felt desirable to limit the stocking densities to a lesser number. Aquaculture experiments, at two different stocking densities of 25 Nos./Sq.m. and 50 Nos /Sq.m. in two different cage sizes of 2 x 2 x 1 m and 2 x 1 x 1m respectively were conducted for a period of 182 days from 2nd January to 3rd July, 1980. No supplementary food was given to the caged mullets and they were allowed to grow with the available natural food. At regular intervals of 30 days a 50% random sample of fish was made from each cage and then length and weight measurements were taken. The fishes were then returned to their respective cages. Such a procedure was repeated till the close of the experiment. From the data so obtained, percentage of average monthly increment in length and weight were computed.

3.2.1 <u>Growth rate of mullet *Liza macrolepis* (Smith) under culture conditions in Adyar estuary, Madras</u>

The results of the environmental impact assessment using mullets as bioassay organisms are summarised in

TABLE 34 EFFECT OF CAGE SIZE AND STOCKING DENSITY ON THE GROWTH RATE OF L. MACROLEPIS AQUACULTURE EXPERIMENTS_ADYAR ESTUARY (JANUARY TO JULY 1980)

CAGE SIZE 2 X 2 X 1 m = 4 Sq.m.

MONTH	NUMBER OF FISH RELEASED	PERCENTAGE OF SURVIVAL	LENGTH RANGE (mm)		AVERAGE LENGTH (mm)		AVERAGE WEIGHT (gm)		GAIN IN BIOMASS WEIGHT (in gm)		AVERAGE GROWTH INCREMENT		PERCENTAGE INCREASE	
			INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	LENGTH (mm)	WEIGHT (gm)	LENGTH (mm)	WEIGHT (gm)
FEBRUARY	100	100	80-85	95-103	82.30	100.42	5.94	9.90	-	396	18.12	3.96	18.64	20.34
MARCH	100	100	95-103	110-118	100.42	117.66	9.90	13.34	396	740	17.24	3.44	17.73	17.67
APRIL	100	100	100-118	125-135	117.66	134.28	13.34	16.70	740	1,076	16.62	3.36	17.09	17.26
MAY	100	100	125-135	142-154	134.28	149.90	16.70	19.80	1,076	1,412	15.62	3.10	16.06	15.93
JUNE	100	98	142-154	154-165	149.90	165.28	19.80	22.70	1,412	1,702	15.38	2.90	15.82	14.90
JULY	100	95	154-165	168-180	165.28	179.50	22.70	25.40	1,702	1,972	14.22	2.70	14.62	13.87

TABLE 35 EFFECT OF CAGE SIZE AND STOCKING DENSITY ON THE GROWTH RATE OF *L. MACROLEPIS* AQUACULTURE EXPERIMENTS-ADYAR ESTUARY (JANUARY TO JULY 1980)

CAGE SIZE 2 X 1 X 1 m = 2 Sq.m.

MONTH	NUMBER OF FISH RELEASED	PERCENTAGE OF SURVIVAL	LENGTH RANGE (mm)		AVERAGE LENGTH (mm)		AVERAGE WEIGHT (gm)		GAIN IN BIOMASS WEIGHT (in gm)		AVERAGE GROWTH INCREMENT		PERCENTAGE INCREASE	
			INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	LENGTH (mm)	WEIGHT (gm)	LENGTH (mm)	WEIGHT (gm)
FEBRUARY	100	100	78-85	98-106	83.15	102.61	6.20	10.30	-	410	19.46	4.10	19.15	19.90
MARCH	100	100	98-106	116-125	102.61	120.29	10.30	13.80	410	760	17.68	3.50	17.45	16.99
APRIL	100	100	116-125	132-140	120.29	137.82	13.80	17.30	760	1,110	17.53	3.50	17.30	16.99
MAY	100	100	132-142	148-158	137.82	154.33	17.30	20.55	1,110	1,435	16.51	3.25	16.29	15.77
JUNE	100	95	148-158	162-174	154.33	169.45	20.55	23.80	1,435	1,755	15.12	3.20	14.92	15.53
JULY	100	90	162-174	178.188	169.45	184.46	23.80	26.80	1,755	2,055	15.01	3.00	14.81	14.56

GROWTH RATE OF MULLET L. macrolepis UNDER CULTURE CONDITIONS IN ADYAR ESTUARY MADRAS

FIG. 36 Experiment No.1

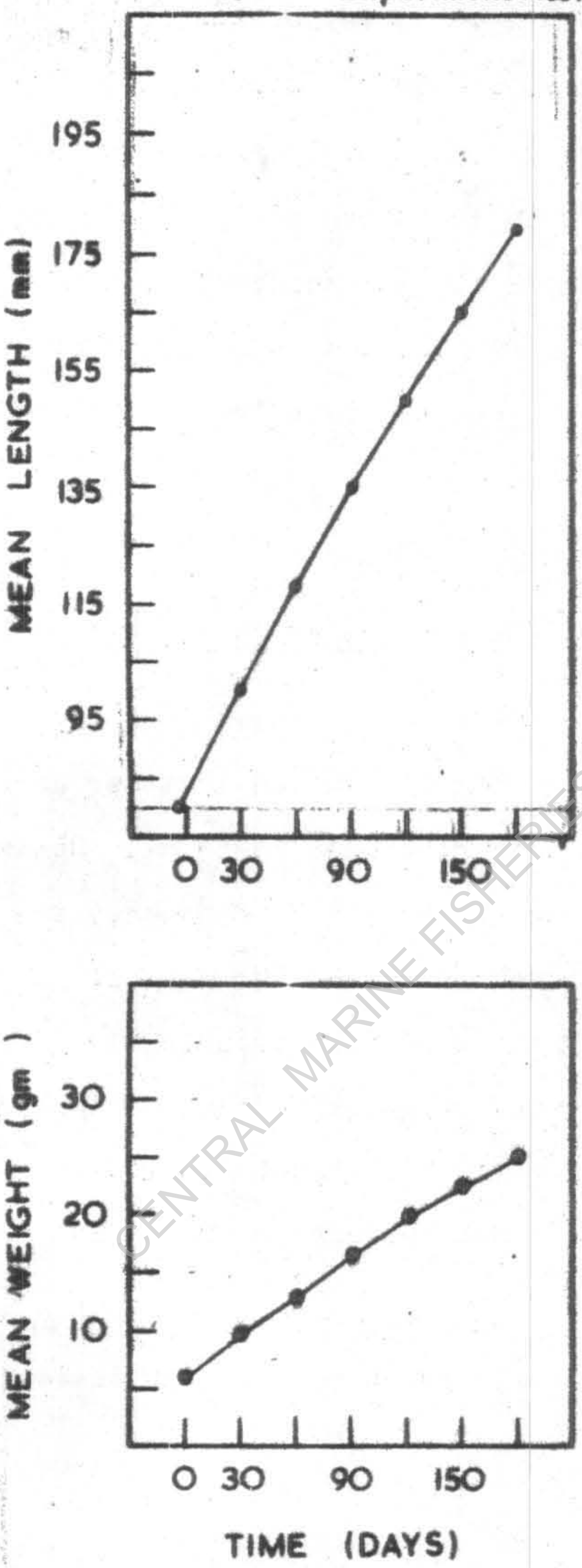
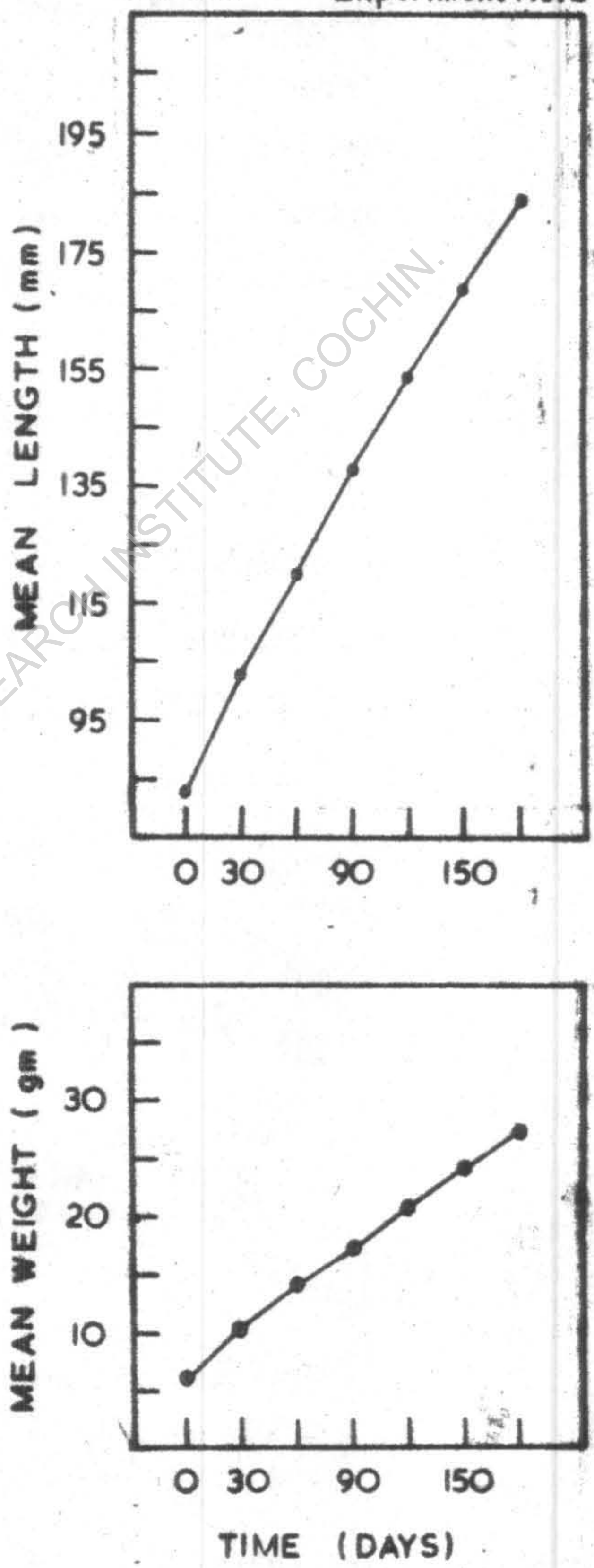


FIG. 37 Experiment No.2



Tables 34 & 35 and Figs. 36 & 37. It may be seen from Tables 34 & 35 that 100% survival rate of mullets were observed for a period of four months i.e. from January to April. Mortality was noticed in the month of May and June, the percentage mortality being 2 to 5%. About 40% of the mullets died during the middle of July and 100% mortality was noticed at the end of July subsequent to the closure of the river mouth.

<u>Experiment No.1:</u>

<u>Biomass increase under a stocking density of 25 Nos/Sq.m. in the cage size 2 x 2 x 1 m</u>

It may be seen from Table 34 that average increase in length of the fish per month varied between 14-18 mm. Maximum increase in length was observed in the month of January and minimum was recorded in the month of June. The overall average of all the monthly averages of fish amounted to 16 mm/month for the entire period of experimentation. During the 182 days of experimentation the fish length increased from 82 mm to 179 mm, thus showing a net increase of 97 mm in length.

The test of linear regression for length is expressed as $y = 132.57 + 16.17\ x$.

Similarly, the average increase in weight of the fish ranged from 2.7 to 3.9 gm per month. Maximum and minimum increase in weight were observed in the month of January and June respectively. The overall average of the average monthly increments in weight of fish was 3.2 gm during the 182 days experimentation. At the termination of the experiment, the weight of fish increased from 5.9 gm to 25.3 gm thus showing a net increase of 19.4 gm in weight. The test of linear regression for weight is represented as $y = 16.14 + 3.17\ x$.

Experiment No.2:

Biomass increase under a stocking density of 50 Nos/Sq.m. in the cage size 2 x 1 x 1 m

It may be seen from Table 35 that 100% survival rate of mullets was observed for a period of four months i.e. from January to April. In the succeeding months about 5 to 10% mortality was observed. The percentage mortality increased during the middle of July, (60%) and 100% mortality occurred at the end of July probably due to altered environmental conditions imposed by the closure of the river mouth.

Based on the results of the experiments as recorded in Table 35, it may be observed that the variation in the increment of length of the fish may range from 15 to 18 mm per month. It was noticed that the increase in length was maximum during January and minimum during June. The average length increment of the fish was estimated as 17 mm/month for the entire period of experimentation. From the initial length of 83 mm, the fishes grew in length to 184 mm during the 182 days experiment, thus showing a net increase of 101 mm in length. The test of linear regression per length is given as $y = 135.85 + 16.75\ x$.

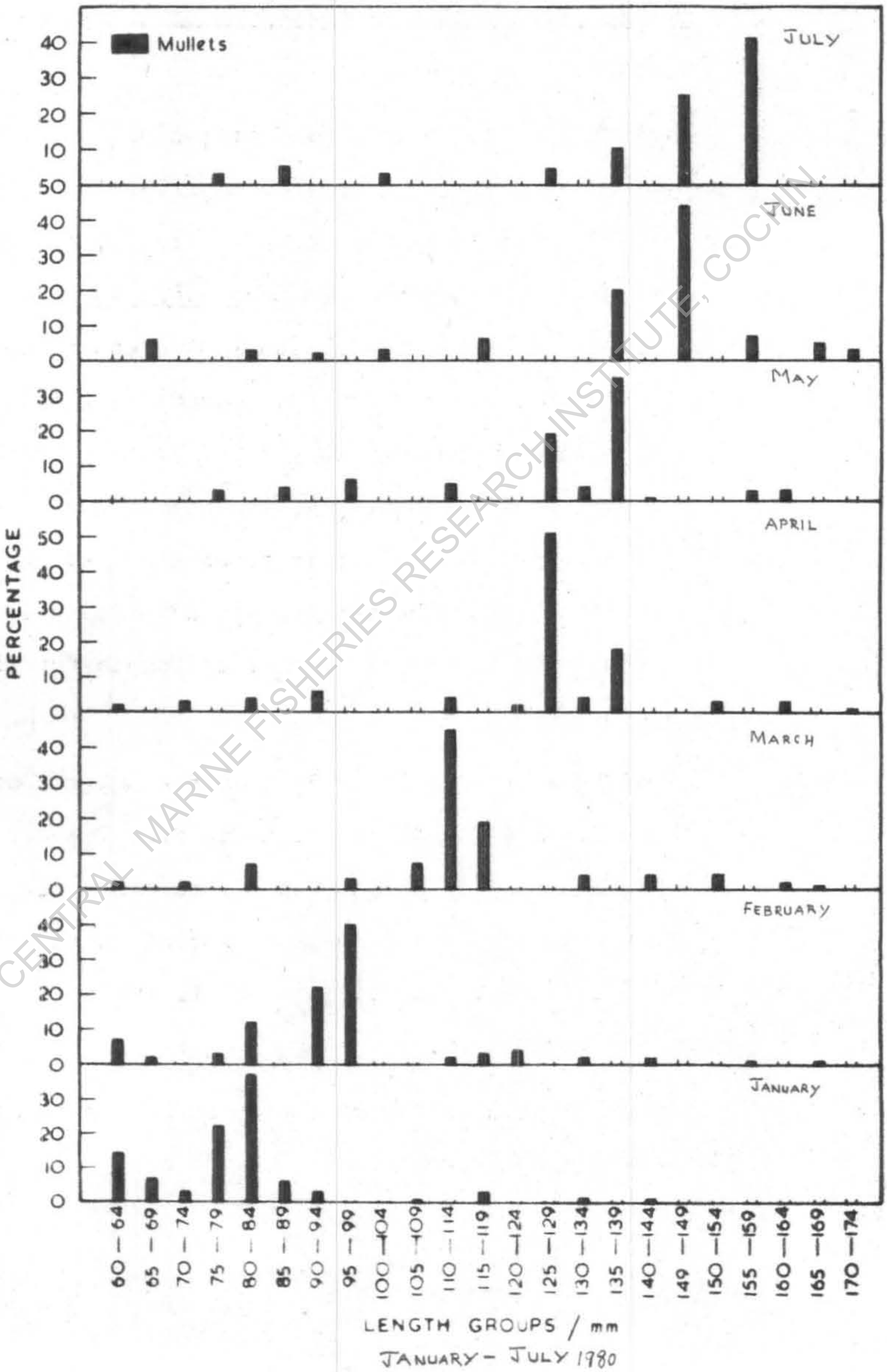
The average weight increase of the fish during the entire period of experiment varied from 3.0 to 4.1 gm per month. Maximum increase in weight was noticed during January and minimum during June. The monthly average increment was in the order of 3.4 gm of fish during the six month experimental period. At the end of 182 days experiment, the weight of fish increased from 6.2 gm to 26.7 gm thus showing a net increase of 20.5 gm in weight.

The results of the above experiments indicate that within a stocking density of 25 Nos/sq.m. and 50 Nos/Sq.m. the biomass production is not affected (Figs. 37 A & 37 B). Hence, it may be inferred that neither cage size nor stocking density appear to affect the growth rates of mullets under the prevailing environmental conditions of the Adyar estuary.

TABLE 36 LENGTH FREQUENCY DATA OF MULLET *L. MACROLEPIS* FROM THE NATURAL POPULATIONS OF ADYAR ESTUARY, MADRAS (JANUARY TO JULY 1980)

SIZE GROUPS (mm)	JANUARY (%)	FEBRUARY (%)	MARCH (%)	APRIL (%)	MAY (%)	JUNE (%)	JULY (%)
60-64	14.49	6.94	1.45	1.41	-	-	-
65-69	7.24	2.08	-	-	1.29	5.68	-
70-74	2.89	-	1.45	2.83	-	-	-
75-79	21.73	3.47	-	-	7.74	-	2.53
80-84	37.38	11.80	7.29	3.54	-	3.40	-
85-89	5.79	-	-	-	6.45	-	5.06
90-94	2.89	22.22	-	5.67	-	2.27	-
95-99	-	40.27	2.91	-	1.29	-	-
100-104	-	-	-	-	12.90	3.40	-
105-109	1.44	-	7.29	-	1.29	-	-
110-114	-	2.08	45.25	4.25	4.51	-	2.53
115-119	2.89	2.77	18.97	-	-	5.68	-
120-124	-	3.47	-	2.12	-	-	-
125-129	-	-	-	51.06	19.35	-	3.79
130-134	1.44	1.38	3.64	4.25	3.22	-	-
135-139	-	-	-	17.73	34.83	20.45	10.12
140-144	1.44	2.08	4.37	-	1.29	-	-
145-149	-	-	-	-	-	44.31	25.31
150-154	-	-	3.64	2.83	-	-	-
155-159	-	0.69	-	-	2.58	6.81	40.50
160-164	-	-	2.18	2.83	3.22	-	-
165-169	-	0.69	1.45	-	-	4.54	-
170-174	-	-	-	1.41	-	3.40	10.12

FIG. 38 ESTIMATION OF GROWTH RATE OF MULLET *L. macrolepis* FROM NATURAL POPULATIONS OF ADYAR ESTUARY MADRAS



3.2.2 Growth rate of mullet *Liza macrolepis* (Smith) sampled from natural populations of Adyar estuary, Madras

Parallel investigations were carried out in order to assess the pattern of growth rate of mullets inhabiting the Adyar estuary. For length frequency analysis, length measurements of 882 specimens of *Liza macrolepis* (Smith) were recorded. Biweekly random sampling of specimens was made from the operations of 'Periya bandha' valai (gill net) during the period January to July 1980. Using length frequency data at 5 mm intervals, an attempt was made to assess the growth rate. Shift in modes was taken as an indication of growth. The results are summarised in Table 36 & Fig. 38, where the monthly increment in length for six months period are given.

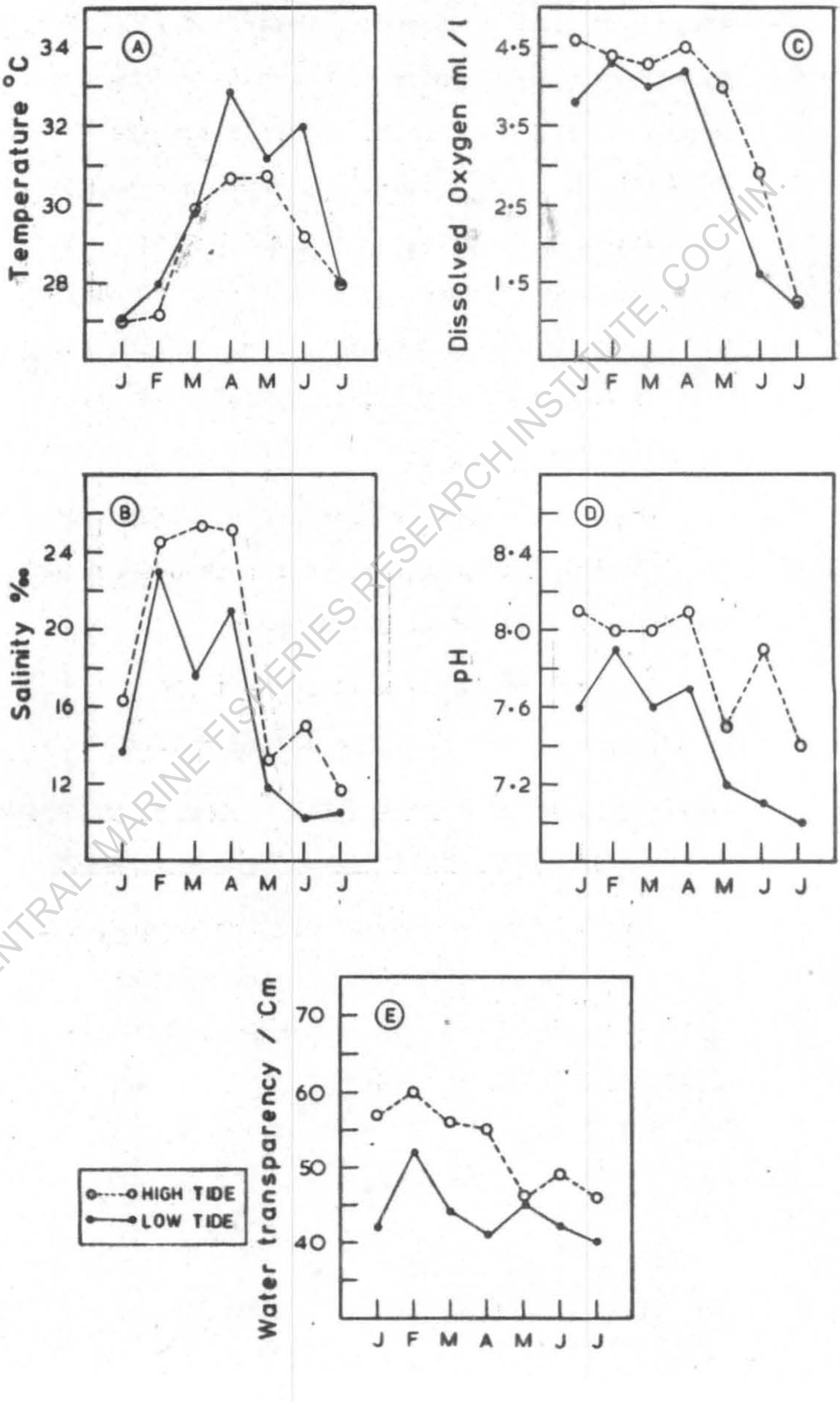
It may be seen from Table 36 that the mullets show a mean increment of 10 to 15 mm per month from January to July. Maximum increment of 15 mm/month was recorded during the month of January and a minimum increment of 10 mm/month was recorded during June. The average of all the monthly averages amounted to 13 mm/month.

The test of regression analysis for length is expressed as $y = 121.57 + 13.28\ x$.

TABLE 37 HYDROLOGICAL DATA FOR THE ADYAR ESTUARY DURING BIOASSAY/AQUACULTURE EXPERIMENTS (JANUARY TO JULY 1980)

MONTH	TIDE	TEMPERATURE °C		SALINITY S ‰	DISSOLVED OXYGEN ml/l	pH	WATER TRANSPARENCY (cm)	NATURE OF BAR MOUTH
		AIR	WATER					
JANUARY	LOW	28.0	27.1	13.72	3.80	7.6	42	OPEN
	HIGH	28.1	27.0	16.43	4.58	8.1	56	OPEN
FEBRUARY	LOW	31.0	28.0	23.01	4.36	7.9	52	OPEN
	HIGH	28.0	27.2	24.65	4.45	8.0	60	OPEN
MARCH	LOW	29.6	29.8	17.65	4.01	7.6	44	OPEN
	HIGH	30.6	30.0	25.37	4.29	8.0	58	OPEN
APRIL	LOW	32.0	32.9	20.93	4.15	7.7	41	OPEN
	HIGH	30.6	30.7	25.15	4.50	8.2	55	OPEN
MAY	LOW	32.5	31.2	11.86	3.02	7.2	45	OPEN
	HIGH	30.0	30.8	23.26	4.07	7.5	46	OPEN
JUNE	LOW	34.0	32.0	10.30	1.62	7.1	42	OPEN
	HIGH	29.0	29.2	15.05	2.89	7.9	49	OPEN
JULY	LOW	29.8	28.1	11.62	1.22	7.0	40	OPEN
	HIGH	29.0	28.0	10.52	1.32	7.4	46	CLOSED

FIG.39 FLUCTUATIONS IN (A) TEMPERATURE (B) SALINTY (C) DISSOLVED OXYGEN (D) pH AND (E) WATER TRANSPARENCY IN ADYAR ESTUARY MADRAS DURING BIOASSAY / AQUACULTURE TEST PERIOD FROM JANUARY TO JULY 1980



From the results of the culture experiments, it is known that with a stocking density of 25 Nos/Sq.m. there is an average increment of 16 mm in length and 3.2 gm in weight of the fish/month. Similar results were obtained when the stocking density was increased to 50 Nos/Sq.m. suggesting thereby that neither stocking density nor cage size appear to affect the growth rate of mullets. Since the length increment of natural populations are lesser than that of cultural mullets, it is inferred that the growth rate of mullets in cages may be faster than uncaged fishes.

The test of linear regression carried out for the significance of difference in length between cultured and natural populations is given below:

Cultured mullet $y = 135.85 + 16.75\,x$

Natural population $y = 121.57 + 13.28\,x$

3.2.3 Hydrological monitoring of the Adyar estuary, Madras during bioassay/aquaculture test period

Hydrological data such as temperature, salinity, dissolved oxygen, p^H and water transparency were collected, while conducting the bioassay/aquaculture experiments in Adyar estuary during January to July 1980 (Table 37 & Fig. 39).

Temperature: The temperature variation ranged from 27.0°C to 32.9°C. Maximum temperature was recorded during low tide in April, the value being 32.9°C. Minimum temperature of 27.0°C was recorded during high tide period in January.

Salinity: The variation in salinity ranged from 10.30%. to 25.37%. . A peak salinity of 25.37%. was recorded during high tide period in March. Low salinity was observed during low tide in June, the value being 10.30%.

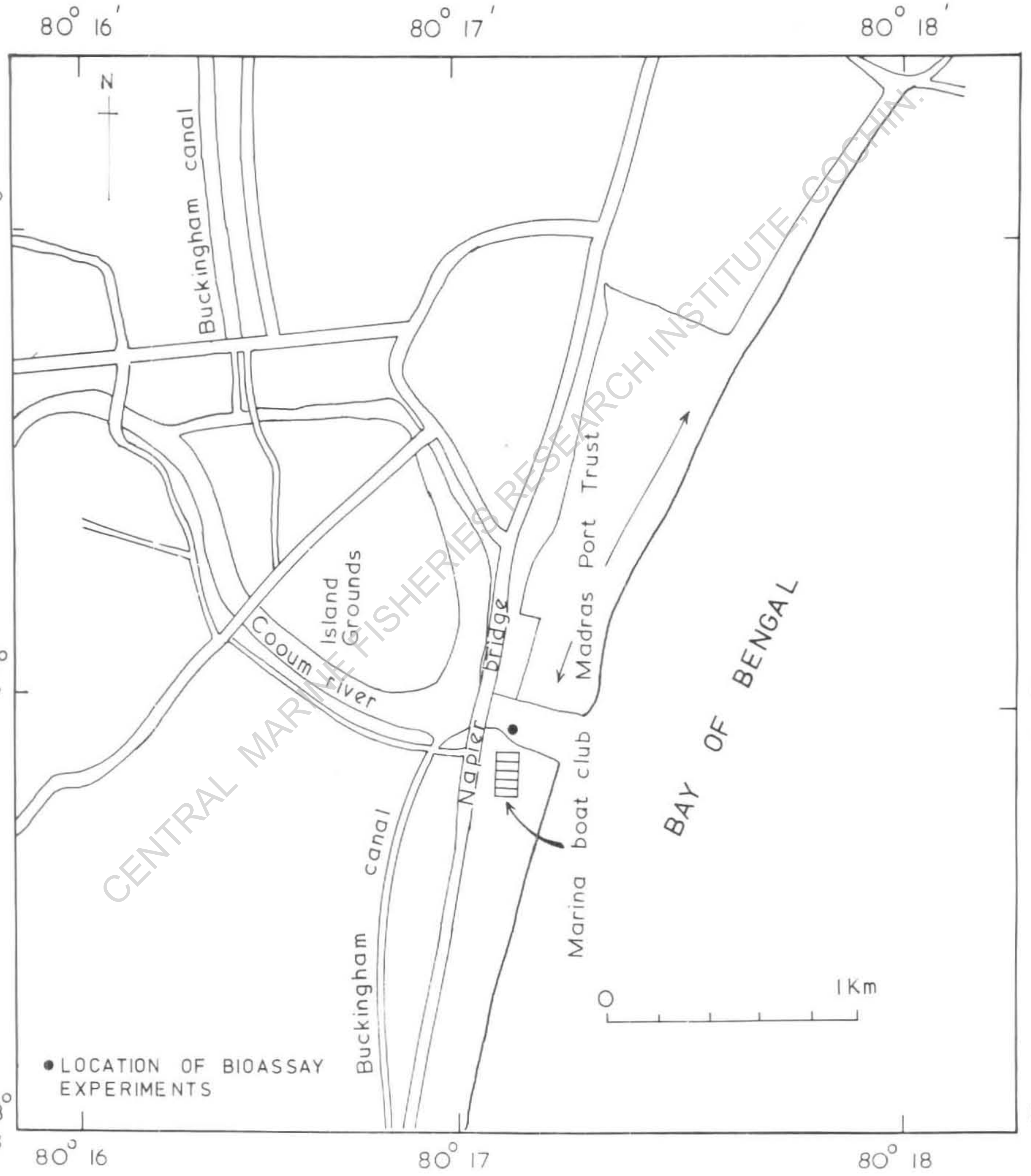
Dissolved Oxygen: The dissolved oxygen content ranged from 1.22 ml/l to 4.58 ml/l. Maximum DO content was observed during the high tide period in January, the value being 4.58 ml/l. Minimum DO content of 1.22 ml/l was observed during low tide period in July.

p^H: The p^H variation ranged from 7.0 to 8.2. The peak p^H of 8.2 was observed during high tide in April. The p^H was low during low tide in July, the value being 7.0.

Water transparency: The secchi-disc depth used as a measure of transparency of the water ranged from 40 to 60 cm. Maximum depth recording of 60 cm indicated the prevalence of clear water during February. Minimum depth was measured during low tide in July, the value, being 40 cm.

FIG. 40

MAP OF A PORTION OF COOUM RIVER SYSTEM MADRAS SHOWING LOCATION OF BIOASSAY EXPERIMENTS



● LOCATION OF BIOASSAY EXPERIMENTS

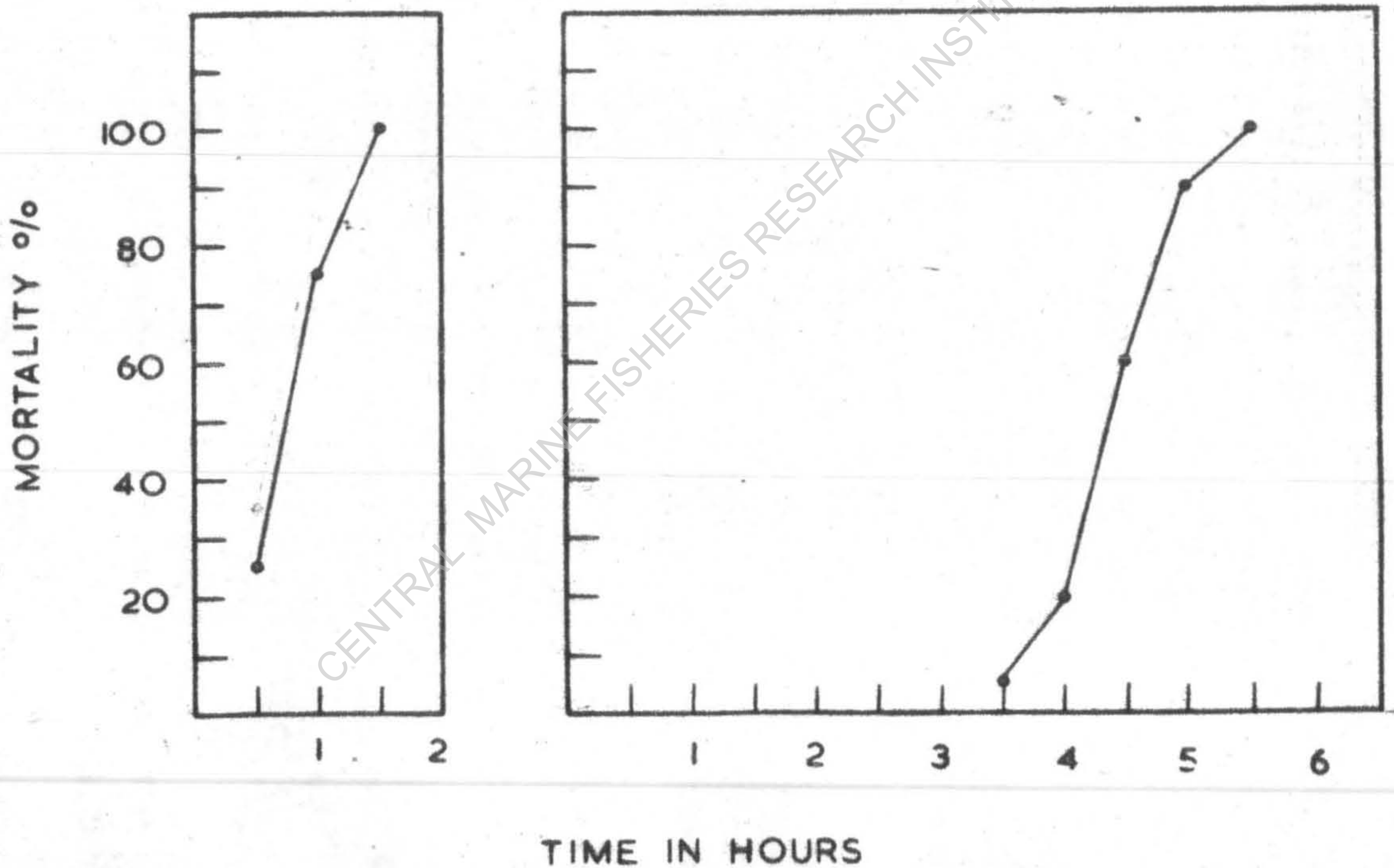
Table 38 Field bioassay test - Cooum river estuary (January to July 1980) Time Vs mortality of *L. macrolepis*: Phase of the tide-Low tide

No. of tests	After/h 0	$\frac{1}{2}$	1	$1\frac{1}{2}$
		Percentage of mortality in hours		
1	-	50	50	-
2	-	-	50	50
3	-	50	50	-
4	-	-	50	50
5	-	-	50	50
6	-	50	50	-
Cumulative percentage of mean mortality	-	25	75	100

TIME Vs MORTALITY RATE OF MULLET *L. macrolepis* IN COOUM ESTUARY MADRAS

FIG 41
Low tide

FIG 42
High tide



3.2.4 Time Vs mortality rate of mullet, *Liza macrolepis* (Smith) in Cooum estuary, Madras

Bioassay tests, under field conditions were carried out to find out the time Vs mortality rates of the euryhaline mullets of the species *Liza macrolepis* (Smith), the experimental site being the Cooum River estuary (13^{0} 4'N and 80^{0} 17' E) Madras (Fig.40). A series of twelve tests with mullet fingerlings of the length and weight ranging from 80 to 85 mm and 5.0 to 5.5 gm was conducted from the month of January to July 1980. In each month two sets of experiments were carried out to study the effect, if any, of the tidal phases of the estuary. The results are presented in Tables 38 & 39 and Figs. 41.& 42. During the course of experimental study hydrological monitoring was carried out. The results are summarized in Table 40.

During the six months period, a total number of six tests were conducted spacing each experiment so as to fall during the high tide phase and the other six experiments were started during the low tide phase. Interpretation of data is based both on the monthly as well as on the average values of all the six experiments conducted during the high and low tide periods. Such a treatment of data was oreferred for the sake of uniformity in treatment of results.

Results of the tests undertaken during the high tide show that the survival time is restricted to about 4½ to 5½ hrs. One hundred per cent survival rate may be maintained upto 3½ hours from the time of release of the fingerlings. With the onset of low tide, the survival rate steadily decreased to about 60% within a period of 4-4½ hrs. and total mortality was recorded in about 4½ to 5½ hrs.

The hydrological conditions of the water during the high tide period of the tests revealed that salinity ranged from 8.87 to 34.13‰. In the course of the experiment it was observed that the temperature of the medium fluctuated by 2 to 3°C. It varied from 28.6 to 33.0°C during the six months period. The dissolved oxygen content of the water ranged from 4.24 to 5.03 ml/l and the pH ranged from 8.0 to 8.4. The secchi-disc depth used as a measure of transparency of the water ranged from 46 to 98 cm.

Based on the studies conducted during low tide periods, it may be seen that the duration of survival period was greatly reduced even within a period of 30 minutes after release. The mortality rate touched 75% level in a period of 60 minutes. One hundred per cent mortality was recorded between 60 minutes and 90 minutes.

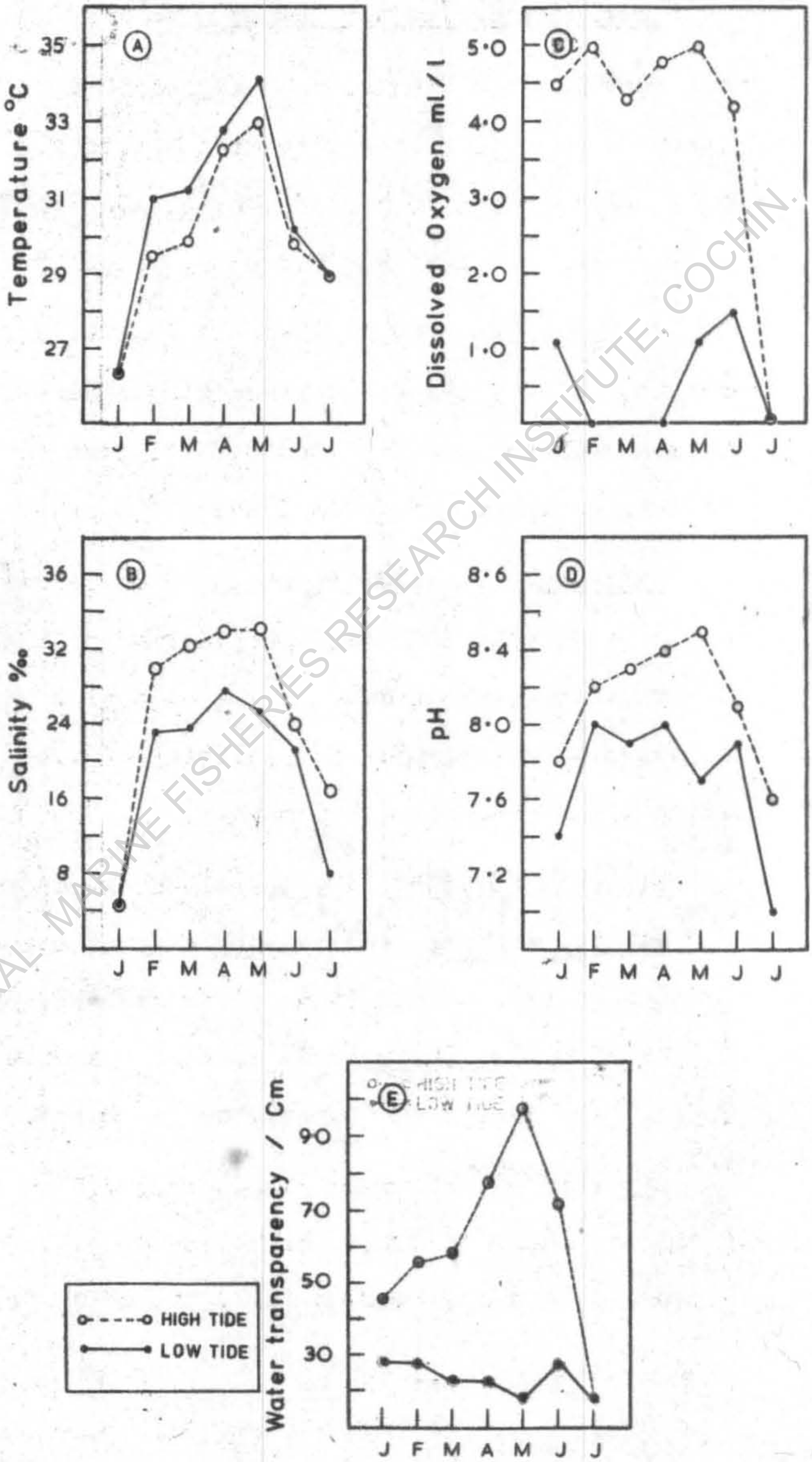
It may be observed from the hydrological conditions of the water prevailing during the low tide periods that the salinity may range from 4.89 to 26.76‰. Temperature fluctuated by 3 to 4 $^{\circ}C$ and it ranged from 30.2 to 34.1 $^{\circ}C$ during the six months period. The dissolved oxygen content of the water ranged from zero to 1.48 ml/l. The p^H ranged from 7.5 to 8.9. The depth for transparency of the water ranged from 19 to 28 cm.

The cause of mortality may be due to drastic variation in the three environmental master factors such as salinity, temperature and dissolved oxygen or of their combinations. It is known that mullets tolerate wide fluctuations of temperature and salinity (Thomson, 1954, 1966, Kinne, 1964, Luther, 1967 and Pillai, 1972). There was drastic Oxygen depletion in the medium. It is, therefore, reasonable to infer that the high mortality may be accounted as due to the lack of oxygen in the medium. The fact that the survival period of mullets is influenced by the phase of the tide may provide circumstantial evidence that the mortality may be due to deoxygenation of the medium due to high pollution load in this river water and on the other hand survival rate may be enhanced due to the inflow of oxygen rich high tide water.

TABLE 40 HYDROLOGICAL DATA FOR THE RIVER COOUM ESTUARY DURING BIOASSAY EXPERIMENTS (JANUARY TO JULY 1980)

MONTH	TIDE	TEMPERATURE °C		SALINITY S ‰	DISSOLVED OXYGEN ml/l	pH	WATER TRANSPARENCY (cm)	NATURE OF BAR MOUTH
		AIR	WATER					
JANUARY	LOW	27.0	26.4	4.89	1.12	7.5	28	OPEN
	HIGH	27.2	26.6	8.87	4.47	7.8	46	OPEN
FEBRUARY	LOW	30.0	31.0	23.01	0.00	8.0	28	OPEN
	HIGH	30.9	29.5	30.01	5.03	8.2	56	OPEN
MARCH	LOW	29.5	31.2	23.31	0.00	7.9	23	OPEN
	HIGH	30.1	29.9	32.67	4.31	8.3	59	OPEN
APRIL	LOW	31.5	32.8	26.74	0.00	8.0	22	OPEN
	HIGH	30.6	32.3	34.13	4.80	8.4	78	OPEN
MAY	LOW	33.3	31.1	25.31	1.12	7.7	19	OPEN
	HIGH	31.2	33.0	32.21	5.03	8.5	98	OPEN
JUNE	LOW	29.0	30.2	21.24	1.48	7.9	28	OPEN
	HIGH	29.5	29.8	24.20	4.24	8.1	72	OPEN
JULY	LOW	29.1	30.9	20.75	1.24	7.8	24	OPEN
	HIGH	29.0	30.1	27.34	4.64	8.2	68	OPEN

FIG. 43 SEASONAL FLUCTUATIONS IN (A) TEMPERATURE (B) SALINITY (C) DISSOLVED OXYGEN (D) pH AND (E) WATER TRANSPARENCY IN COOUM ESTUARY MADRAS DURING THE BIOASSAY PERIOD FROM JANUARY TO JULY 1980



3.2.5 <u>Hydrological monitoring of the Cooum estuary, Madras during the bioassay period</u>

Hydrological data such as temperature, salinity, dissolved oxygen, p^H and water transparency were obtained while undertaking the bioassay experiment in Cooum estuary during June to July 1980 (Table 40 & Fig. 43).

<u>Temperature:</u> The variation in temperature ranged from 26.4°C to 34.21°C. Maximum temperature of 34.1°C was observed during high tide in May. Minimum temperature was observed during low tide in January, the value being 26.4°C.

<u>Salinity</u>: The wide fluctuation in salinity was observed during January to July 1980 and it ranged from 4.89 to 34.13%. Peak salinity was recorded during high tide period in April, the value being 34.13%. Low salinity of 4.89%. was recorded during low tide period in January.

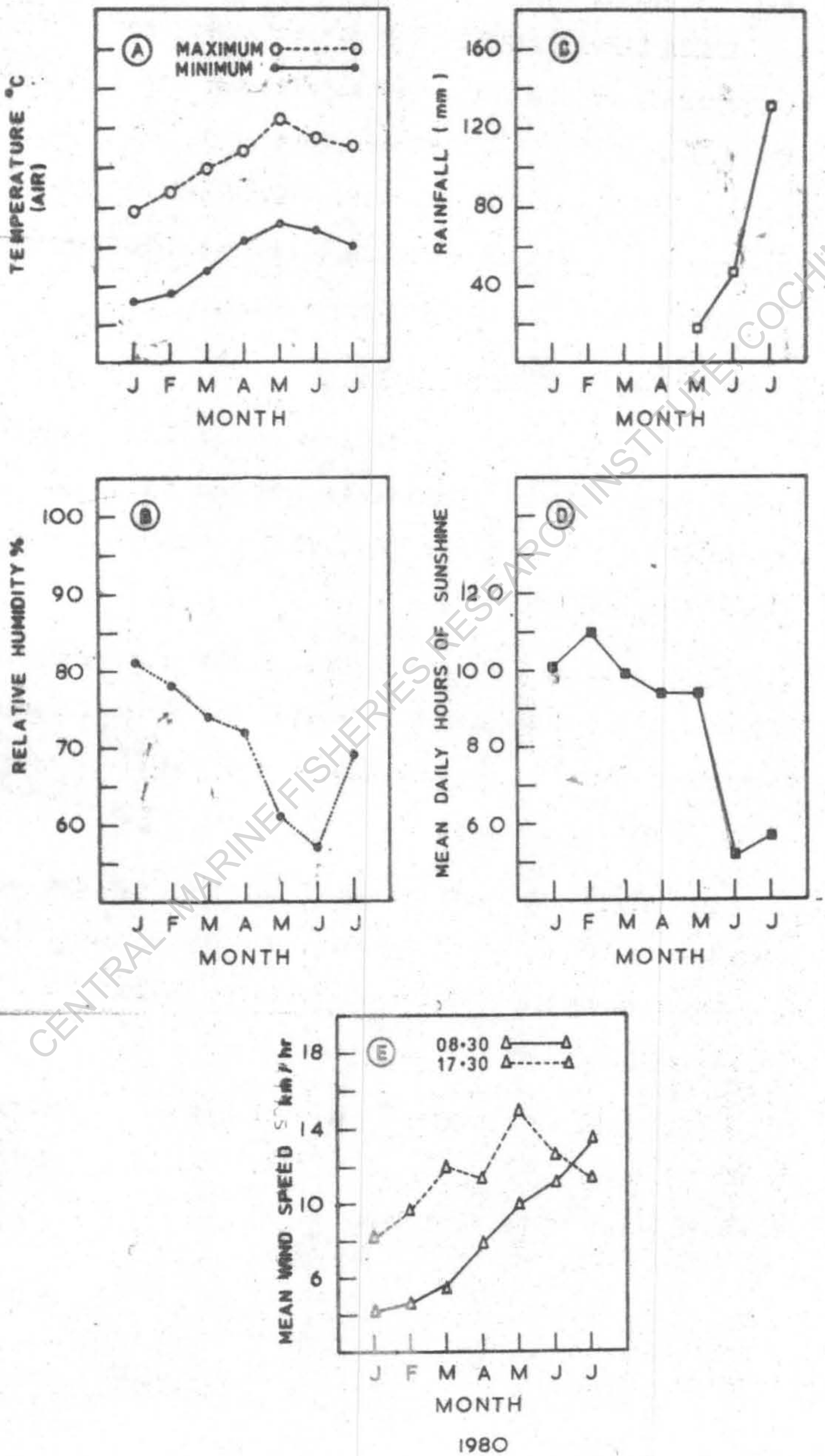
<u>Dissolved Oxygen:</u> The dissolved oxygen content ranged from zero to 5.03 ml. Maximum DO content was observed during high tide period in February and May, the value being 5.03 ml/l. The zero DO content was observed during the low tide period in February and in March.

<u>p^H:</u> The p^H variation ranged from 7.0 to 8.5. Peak p^H of 8.5 was recorded during high tide in May. Low p^H was recorded during low tide in July, the value being 7.0.

Table 41 Meteorological data for the period from January to July 1980-Madras

Month	Mean air temperature oC		Percentage of relative humidity	Total rain fall (mm)	Average daily hours of sunshine	Mean wind speed km/hr	
	Minimum	Maximum				0830 hrs	1730 hrs
January	20.4	29.8	81.24	00.0	10.16	04.2	08.2
February	21.3	31.5	77.86	00.0	10.97	04.7	09.6
March	23.6	34.1	74.53	00.0	9.94	05.7	11.8
April	26.7	35.6	72.06	00.0	9.37	07.9	11.5
May	28.5	39.0	61.13	10.8	9.37	10.0	15.1
June	27.6	37.1	57.02	47.0	5.19	11.2	12.7
July	26.0	36.1	69.10	130.1	5.74	13.5	11.7

FIG. 44 SEASONAL FLUCTUATIONS IN (A) AIR TEMPERATURE (B) RELATIVE HUMIDITY (C) RAIN FALL (D) DAILY HOURS OF SUNSHINE AND (E) WIND SPEED IN MADRAS DURING THE BIOASSAY / AQUACULTURE TEST PERIOD FROM JANUARY TO JULY 1980



Water transparency: The variation in depth for transparency of the water was significant and it ranged from 1.8 cm to 98 cm. Maximum depth of 78 cm observed during high tide in April and minimum depth of 18 cm measured during the month of July indicate the extent of turbidity due to the particulate matter.

3.2.6 Meteorological observations

Meteorological data were obtained while conducting bioassay/aquaculture experiments in Adyar and Cooum estuaries from January to July, 1980 and is presented in Table 41 & Fig. 44.

Temperature: The atmospheric temperature showed a bimodal oscillation with two maximal and minimal periods. The temperature was maximum (39.9°C) during May and minimum (20.4°C) during January.

Humidity: The percentage of relative humidity was high during the month of January, the value being 81.24%. Minimum percentage of relative humidity (57.02%) was recorded during June.

Rainfall: The average rainfall was maximum during the month of July, the value being 130.1 mm. The rainfall was minimum (10.8 mm) during May.

TABLE 42 A PERCENTAGE MORTALITY OF MULLET L. MACROLEPIS IN DIFFERENT CONCENTRATIONS OF MERCURY IN STATIC BIOASSAY TESTS.

S. NO.	24 h Lc 50 (Hg) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (IN PERCENTAGE)	RESULTED Lc 50 (Hg) (ppb)
1	380	10-30	20	
2	400	40-60	50	405
3	430	70-90	80	

S. NO.	48 h Lc 50 (Hg) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (IN PERCENTAGE)	RESULTED Lc 50 (Hg) (ppb)
1	365	10-30	20	
2	375	40-60	50	380
3	390	70-90	80	

S. NO.	72 h Lc 50 (Hg) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (IN PERCENTAGE)	RESULTED Lc 50 (Hg) (ppb)
1	340	10-30	20	
2	360	40-60	50	370
3	380	70-90	80	

S. NO.	96 h Lc 50 (Hg) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (IN PERCENTAGE)	RESULTED Lc 50 (Hg) (ppb)
1	320	10-30	20	
2	350	40-60	50	360
3	370	70-90	80	

Table 43 Physical and chemical characteristics of the water used in static bioassay experiments

Name of the species	Length (mm)	Weight (gm)	Temperature ^{o}C	Salinity %	Dissolved oxygen concentration range ml/l	p^{H}	Hardness* total alkalinity (ppm)
L. macrolepis	80 ± 5	5.0 ± 0.5	29 °C ± 1 °C	15% ± 1%	3.5 ± 0.5	7.5 ± 1	124 ± 1

*Hardness is used here as convenient shorthand for a number of factors such as Ca, Co_3 value as total alkalinity.

Table 44 Results of Static bioassay tests conducted with mullet *Liza macrolepis* (Smith) with reference to heavy metals (mercury and cadmium) at salinity 15%, temperature 29° C ± 1° C

Name of the toxicant	Duration of time in hours	Lc 50 (ppb)	Lower limit	Upper limit	Slope function	Lc 84	Lc 16
	24 h	405	393.2	417.1	1.06	420	370
	48 h	480	368.9	391.4	1.03	400	360
Mercury	72 h	370	339.8	381.5	1.07	380	350
	96 h	360	329.6	365.5	1.14	370	315
	24 h	4145	4677.2	5259.5	1.06	5545	4245
	46 h	4410	3834.7	4510.5	1.14	5210	3870
Cadmium	72 h	3675	3223.6	4189.5	1.14	4275	3275
	96 h	2940	2722.2	3175.2	1.39	3450	2360

observed that there is a relationship between the percentage mortality and the concentration of toxicants in the ambient medium. Data on the various levels of Lc 50 concentrations are necessary components to work out the "application factor" in order to assess the safe level concentrations of toxicants.

The data so obtained were plotted on a log probit chart No.32,376 (supplied by Codex Co. Norwood, Massachutes, U.S.A.) which gives a simple solution of the dose-effect curve with 95% confidence limits for Lc 50 Values. Further, lower and upper limits and slope function (S) were also computed.

The slope function (S) is anologus to slope constant 'b' in that the variability of a test population is indicated by the slope of the line obtained by plotting percentages of deaths against concentration of the heavy metals on a logrithmic probability paper (Litchfield and Wilcoxon, 1949). The slope function was calculated by using the following formula proposed by Litchfield and Wilcoxon (1949).

$$S = \frac{(Lc\ 84/Lc\ 50 + Lc\ 50/Lc\ 16)}{2}$$

The corresponding values for Lc 84 and Lc 16 were computed from the graph. The variation in susceptability of the fish population to the heavy metals was denoted numerically by the slope function. Higher values of the slope function indicates the greater variability in susceptability of the population to the test substance in question. The results are presented in Table 44.

3.3.1 Evaluation of dose-effect response of the mullet *Liza macrolepis* (Smith) with reference to mercury and cadmium

It may be seen from Table 44 that the Lc 50 value of mercury for mullet *L. macrolepis* at 24 h was estimated as 405 ppb. Lower and upper limits of the concentrations were found to range from 393.2 to 417.1 ppb. A slope function of 1.06 (S) for 24 h period was obtained. The Lc 84 and Lc 16 values were computed as 420 and 370 ppb respectively.

The 48 h Lc 50 value, the lower and upper limits of 48 h Lc 50 were 380.0, 368.9 and 391.4 ppb respectively. The value of the slope of the concentration percentage mortality curve at 48 h was decreased to 1.03 thus indicating the lesser variation in susceptibility of the mullet (see Fig. 45). The confidence limits for Lc 84 and Lc 16 were 400 and 360 ppb respectively.

At 72 h, the Lc 50 value of 370 ppb was recorded with a lower and upper limits of 339.8 and 381.5 ppb. The value of slope function increased to 1.07. The Lc 84 and Lc 16 confidence limits were computed as 380 and 330 ppb respectively. It is inferred that with the increase in the duration of exposure, the variability in susceptibility is also increased.

TABLE 42 B PERCENTAGE MORTALITY OF MULLET, *L. MACROLEPIS* IN DIFFERENT CONCENTRATIONS OF CADMIUM IN STATIC BIOASSAY TESTS

S. NO.	24 h Lc 50 (Cd) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (PERCENTAGE)	RESULTED Lc 50 (Cd) (ppb)
1	4800	10-30	20	
2	5100	40-60	50	5145
3	5500	70-90	80	

S. NO.	48 h Lc 50 (Cd) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (PERCENTAGE)	RESULTED Lc 50 (Cd) (ppb)
1	3800	10-30	20	
2	4400	40-60	50	4410
3	5200	70-90	80	

S. NO.	72 h Lc 50 (Cd) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (PERCENTAGE)	RESULTED Lc 50 (Cd) (ppb)
1	3200	10-30	20	
2	3600	40-60	50	3675
3	4200	70-90	80	

S. NO.	96 h Lc 50 (Cd) CONCENTRATION (ppb)	MORTALITY RANGE (IN PERCENTAGE)	MORTALITY MEAN (PERCENTAGE)	RESULTED Lc 50 (Cd) (ppb)
1	2500	10-30	20	
2	3000	40-60	50	2940
3	3400	70-90	80	

Lower and upper limits of the 96 h Lc 50 were determined as 339.6 and 365.5 ppb respectively, the mean being 360 ppb. It is interesting to note a further increase in slope function (1.14) which is indicative of high degree of variation in susceptability of the fish after a 96 h exposure period. The confidence limits for Lc 84 and Lc 16 were computed as 370 and 315 ppb.

Similarly, a series of ten tests was conducted with mullets for different known concentrations of cadmium. Mean percentage mortality of 20%, 50% and 80% for 24 h was recorded. Similar observations were made for 48 h, 72 h and 96 hours (Table 42 B). Concurrently, a control without toxicant was also maintained. It was inferred from the results that the percentage of mortality increases with the increase in the concentration of cadmium.

As has been mentioned earlier, data computed from the use of log probit charts were used for deriving the median lethal concentrations (Lc 50), its lower, upper limits and slope function. Further, the confidence limits of Lc 84 and Lc 16 for mullets at 24 h, 48 h, 72 h and 96 h were computed. The results are given in Table 44.

It is seen from Table 44 that the 24 h Lc 50 value was 5145 ppb and the lower and upper limits at 24 h Lc 50 were

4677.2 and 5259.5 ppb respectively, with a slope function of 1.06. The confidence limits for Lc 84 and Lc 16 were computed as 5545 and 4245 ppb respectively.

The Lc 50 value of 4410 ppb was recorded at 48 h with a lower and upper limits of 3834.7 and 4510.5 ppb. The increase in the value of slope function (1.14) is indicative of the increased susceptability of the test fish populations to cadmium toxicity. The Lc 84 and Lc 16 confidence limits were computed as 5210 and 3870 ppb respectively.

The 78 h, Lc 50, with its lower and upper limits were determined, the values being 3675 ,3225 and 4189.5 ppb respectively. It is interesting to note that there is no variation in slope function between 48 h Lc 50 and 78 h Lc 50. It is reasonable to infer that some degree of tolerance is attained within a period of 78 hours. The 78 h Lc 84 and Lc 16 values showed a lower range of 4275 to 3275 ppb.

At 96 h, the Lc 50 value was estimated as 2940 ppb with a lower and upper limits of 2722.2 and 3175.2 ppb. The variation in susceptability as indicated by the slope function value was determined. High value of 1.39 indicated greater degree of susceptability. The 96 h Lc 84 and Lc 16 confidence limits were computed as 3450 and 2360 ppb respectively.

FIG. 45 Variations in slope function at 96h Lc 50 levels of mercury & cadmium

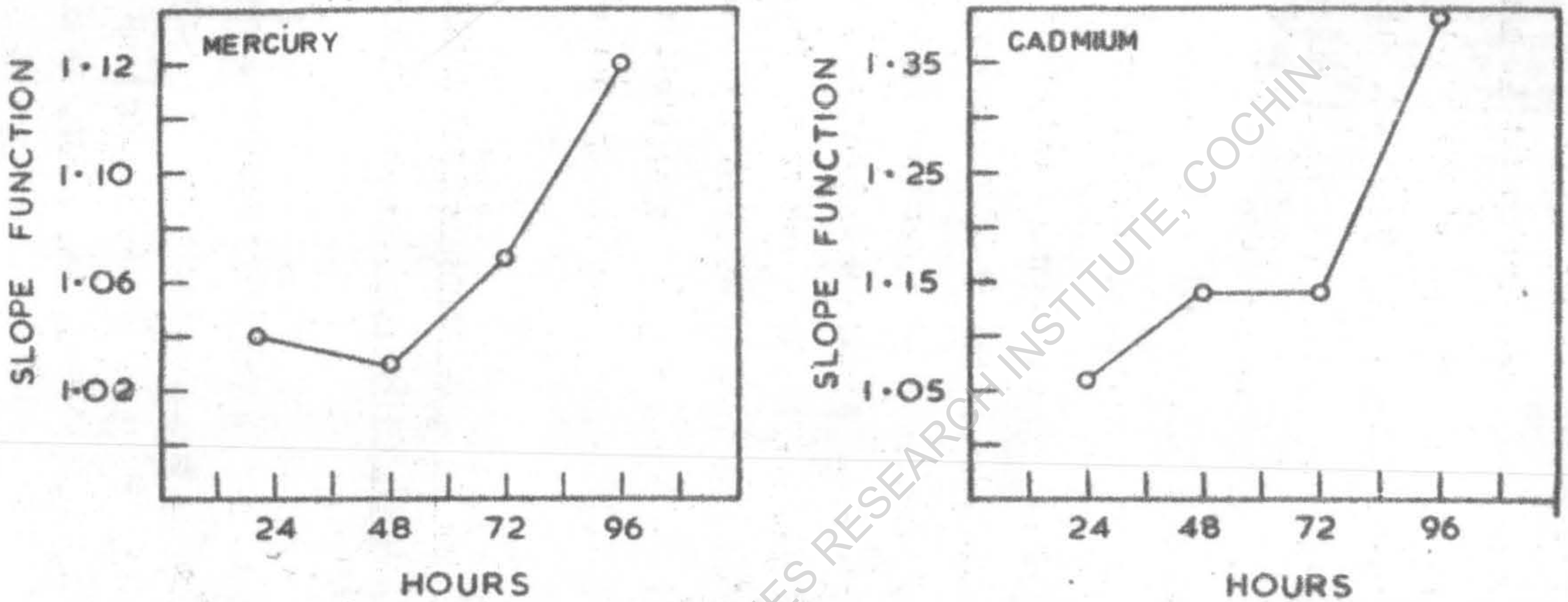
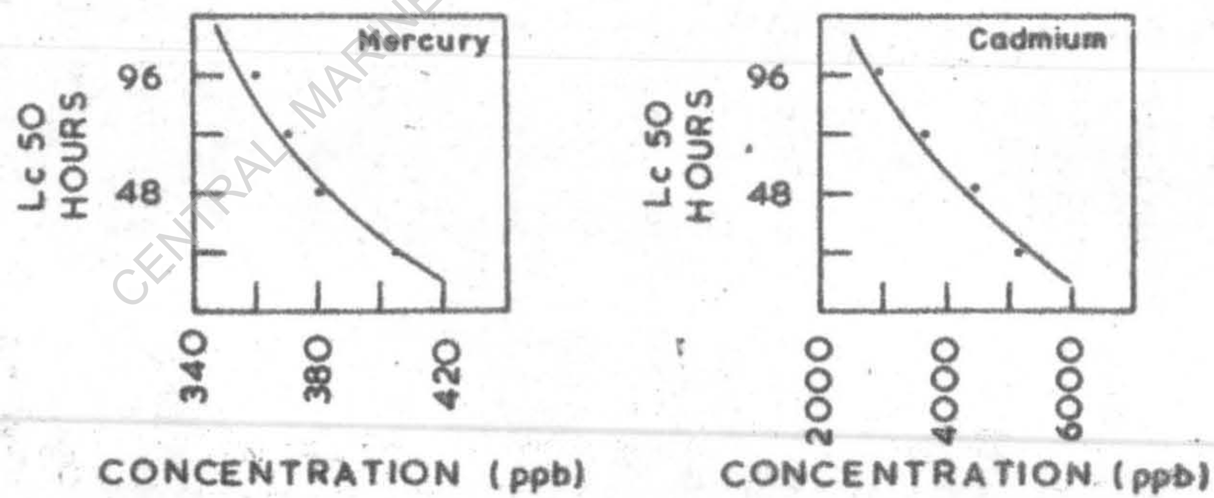


FIG. 46 Toxicity curve for mercury and cadmium



In general, the Lc 50 values for the two heavy metals mercury and cadmium bioassayed against the mullet L. *macrolepis* were progressively declined at each of the observation periods of 24 h, 48 h, 72 h and 96 hours (Fig. 46). This indicates that death in mullets continues to occur during the entire study period. It may be concluded from the relative toxicity tests that mullets are easily susceptable to low concentrations of mercury when compared to cadmium.

In Fig. 45 the values of slope function (s) are plotted against time. It is seen that in the case of mercury, there is a drop in the slope function at 48 h duration followed by a steep rise. In the case of mullets exposed to cadmium the curve showed a plateau between 48 h and 72 h. These results suggest that the pattern of biological response of the fish population to the heavy metals may be similar with a significant change in adaptability between the period of 48 h and 72 h exposure.

3.3.2 Evaluation of 'Safe level' concentration for mullet *Liza macrolepis* (Smith) with reference to mercury and cadmium

"Safe level" may be defined as the concentrations of the pollutants at which fishes can grow and reproduce normally (Basak and Konar, 1977). A number of techniques have been used to predict safe levels employing the values of lethal levels using mathematical or graphical means (Sprague, 1971 and Eaton, 1973). In order to arrive at the safe level concentration, many workers have devised an "application factor" based on the results of static bioassay. By applying this factor attempts have been made to evaluate the safe level concentrations of heavy metals for fishes (Hart, et al., 1945; Herbert et al., 1965; Edwards and Brown, 1966; Tarzwell, 1966; Burdick, 1967; Mount and Stephan, 1967; Mount, 1968; Brungs,1969; Lloyd and Orr, 1969; Eaton, 1970, Sprague, 1971, 1976; Basak and Konar, 1977; Cairns et al., 1979 and Eisler, 1979).

Application factors are more arbitrary numbers which are used as a multiplier of a lethal concentration to arrive at a predicted "safe concentration" for sub-lethal effects (Sprague, 1971).

In reviewing the literature on the use of "application factor" it is seen that there is no uniformity of procedure. In the establishment of a safety factor, Burdick (1967) resorted to the use of a 0.1 factor times the 96 h Lc 50 whereas Edwards and Brown (1966) used 0.4 of the 96 h Lc 50. The European Inland Fisheries Advisory Commission (1965) has recommended the use of 0.25 of 96 h Lc 50 as the application factor. Mount (1968) calculated the factor from the maximum acceptable concentration by dividing it with the static 96 h Lc 50 value.

TABLE 45 EVALUATION OF "SAFE LEVEL CONCENTRATIONS" USING THE STATIC BIOASSAY ESTIMATES AS PROPOSED BY VARIOUS AUTHORS

AUTHORS	Hg (in ppb)	Cd (in ppb)	APPLICATION FACTOR	CONTROL
HART *et al.*, (1945)	110	987	0.30	NO MORTALITY
EUROPEAN INLAND FISHERIES ADVISORY COMMISSION (1965)	90	735	0.25	"
HERBERT (1965) BRUNGS (1969)	72	588	0.20	"
BURDICK (1967) EATON (1970)	36	294	0.10	"
EDWARDS & BROWN (1966)	144	1176	0.40	"
TARZWELL (1966) SPRAGUE (1971) EISLER (1979)	36	294	0.10	"
SPRAGUE (1976)	144	1176	0.40	"
MOUNT & STEPHEN (1967)	46.8	382.2	0.13	"
MOUNT (1968)	110	765	0.51	"
LYOYD & ORR (1969)	43.2	352.8	0.12	"
BASAK & KONAR (1977)	184	1245	$\frac{Lc0}{Lc100}$ X Lc50	"
CAIRNS Jr. *et. al.*,(1979)	20	150	0.10	"

In the present study, an attempt has been made to extrapolate the "presumably harmless condition" using a selected few application factors as recommended by earlier workers. However, more emphasis is given to the formulae of Hart et al., (1945) involving the ratio among 96 h, 48 h and 24 h Lc 50, since it takes into consideration the sensitivity of different individuals and different water conditions. Furthermore, the application factor of 0.3 coincides well with recent estimates based on field studies (Sprague, 1971).

$$\text{Safe concentration} = 0.3/48\text{ h TLM}/(24\text{ h})/48\text{ h }(\text{TLM}/^{2}.$$

Accordingly, the 'safe level concentration' of mercury and cadmium for mullet Liza macrolepis (Smith) was found to be 110 ppb and 987 ppb respectively.

Table 45 summarizes the calculated values of safe level concentration using different application factors, proposed by various authors. It may be seen that none of them exceed the maximum acceptable concentration. In a overall view, the presumably harmless and acceptable 'safe level concentrations' of mercury and cadmium for mullet Liza macrolepis (Smith) inhabiting Adyar estuary appears to be in the range of 20 to 144 ppb for mercury and 150 to 1245 ppb for cadmium respectively. The above values were derived with the use of the application factors recommended by various authors as given in Table 45.

3.4.0 Behavioural responses of mullet, *Liza macrolepis* (Smith) when exposed to 96 h Lc 50 levels of mercury and cadmium

Studies related to pollutant induced behavioural responses on fishes such as feeding, coughing, chasing, flicks, thrusts, comfort, defensive, predation, vulnerability, sexual and aggression behaviours (Hiatt, *et al*., 1953; Goodyear, 1972; Olla *et al*., 1974; Dalela *et al*., 1978; Eisler, 1979; Deacutis, 1979; Lingaraja and Venugopalan, 1978: Lingaraja *et al*., 1979) swimming performance, schooling, migration, learning, conditioning, avoidance reactions, escape response, rhythmic activities (Sprague *et al*., 1965; Brett, 1967; Saunders and Sprague, 1967; Sprague, 1968; Sprague and Drury, 1969; Hansen, 1969; Bengtssen, 1974; Lal and Vohra, 1974; Verma *et al*., 1975; Besch, *et al*., 1977 Lewis and Livingston, 1977; Ovais *et al*., 1977; Marcucella and Abhramson, 1978 and Eisler, 1979) opercular movements, breathing rates and number of visits to the water surface (Belding, 1929; Jones, 1947; Konar, 1969; Morgan and Kuhn, 1974; Lal and Vohra, 1974; Thomas and Rice, 1975; Verma *et al*., 1975; Verma and Dalela, 1976; Rice *et al*., and Dalela *et al*., 1978) have been well documented by many earlier workers.

3.4.1 Swimming performance of mullet, *L. macrolepis*

In the present study, changes in the behavioural responses in mullets *L. macrolepis* when exposed to the

Table 46 A Number of visits/minute to the water surface in mullet <u>Liza macrolepis</u> (Smith) under normal and test conditions

S.No.		Visits/minute (Mean values)				
		After 1 hr	After 24 hr	After 48 hr	After 72 hr	After 96 hr
1	Control	3	3	2	2	1
2	Mercury	10	9	8	8	8
3	Cadmium	8	7	6	7	6

Table 46 B Opercular beats/minute in mullet <u>Liza macrolepis</u> (Smith) under normal and test conditions

S.No.		Opercular beats/minute (Mean values)				
		After 1 hr	After 24 hr	After 48 hr	After 72 hr	After 96 hr
1	Control	12	12	10	12	14
2	Mercury	48	37	36	35	32
3	Cadmium	40	33	31	32	28

following two heavy metals namely mercury and cadmium at 96 h Lc 50 levels were observed for an unit period of 10 minutes. Changes in swimming performance, number of visits to water surface and opercular movements were studied. Responses of five fishes out of ten were observed at random in the following test periods of 24, 48, 72 and 96 hrs. The mean values are presented in Table 46 A. Control experiments were carried out concurrently.

The swimming behaviour of mullets in control experiments were normal. They swim generally at the bottom layer of the water. It may be noted from the results that the mean number of visits of mullets to the surface of the water was in the range of 1-3/minute. When the mullets were in a medium containing mercury, the mean number of visits to the water surface was increased to 8-10/minute. The increase in the number of visits of mullets to the water surface was about 7 times more than the control. The mullets swam restlessly immediately after exposure and at times dashed against the wall of the tank. The swimming activity was sluggish and forward movement was impaired at the end of the test period. Prior to death, they swim laterally and upside down with short jerky movements. The mullets lost their equilibrium and rested on the bottom of the tank with their bellies facing up which is an indication of disability and discomfort.

It has been observed that the mean number of visits of mullets to the water surface in the cadmium treated medium was in the range of 6-8/minute which is about 5 times more than the controls. They swam at the middle layer of water column in the test tank. Their swimming movement was much restricted and they swam at the periphery of the tank at the surface of the water column. Prior to death sluggish lateral movements were observed and finally they succumbed with their bellies turned up. The change in the swimming pattern may be attributed to the stress on the body of the fishes exerted by the toxic substances (Lal and Vohra, 1974; Verma *et al.*, 1975; Verma and Dalela, 1976 and Srivastava *et al.*, 1977).

3.4.2 Opercular movements of mullet, *L. macrolepis*

It may be seen from the results summarised in Table 46 B that the mean number of opercular beats in control mullets ranged from 10-14 beats/minute. When the mullets were exposed to mercury, the mean number of opercular beats was increased to 48/minute during the first hour of exposure and it gradually decreased to 32-37 beats/minute.

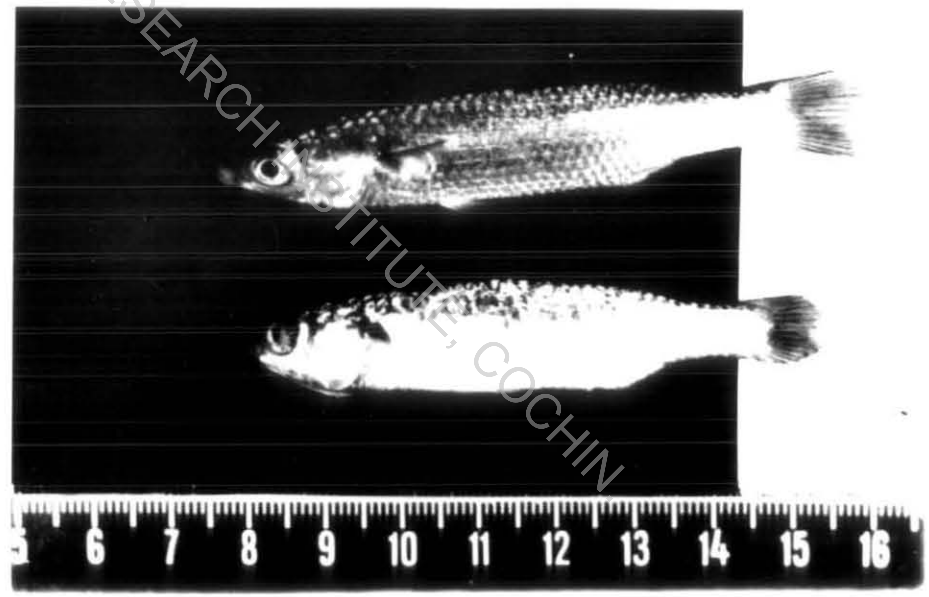
It has been observed that mullets subjected to cadmium, after a period of one hour, increased their opercular beats to 40/minute and then the opercular beat was gradually reduced to 28-33 beats/minute. The increase in the number of opercular beats was not of the same order as in the case of mercury.

FIG. 47

FIG. 48

FIG. 49

FIG. 50



Legend for figures

Fig.47 Photograph showing swelling of the nasal openings when mullets *L. macrolepis* are exposed to mercury.

Fig.48 Spilitting of fin membranes in mullet *L. macrolepis* when exposed to mercury.

Fig.49 Photograph showing scales with blood stains are seen to peel off from the body of *L. macrolepis* when exposed to cadmium.

Fig.50 Caudal fin erosion in mullet *L. macrolepis* when exposed to cadmium.

A rapid increase in the opercular beats of other fishes due to toxicants have been reported by earlier workers (Konar, 1969; Lal and Vohra, 1974; Verma *et al*., 1975 and Verma and Dalela 1976). On the other hand, in the present study, it has been found that the rate of opercular beats was significantly reduced after one hour of treatment of mullets with mercury and cadmium.

3.4.3 Morphological changes in mullet, *Liza macrolepis* (Smith) when exposed to 96 h Lc 50 levels of mercury and cadmium

When mullet *L. macrolepis* were exposed to heavy metals, mercury and cadmium at 96 h Lc 50 levels, the following morphological changes were observed:

When mullets were kept in water containing 360 ppb of mercury, swelling of the nasal openings, impairment of the upper and lower jaw margins, gill inflamation and internal hemorrhages associated with rupture of blood capillaries in lamellae were observed in 50% of the fishes studied (Fig. 47). The normal hemicercal nature of the caudal fin margins became eroded. As a result, irregular fin shape was noticed. The fin rays showed splitting of fin membranes and hemorrhages of fin tissues resulted in darkened tissue at the erosion site (Fig. 48).

TABLE 47 RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF CONTROL MULLET L. MACROLEPIS DURING 96 h CONTINUOUS FLOW BIOASSAY TEST

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
1	0.22	0.20	0.21	0.21	0.20	0.19	0.20	0.0104	0.0073
2	0.19	0.18	0.20	0.19	0.19	0.21	0.19	0.0103	0.0076
3	0.24	0.21	0.20	0.19	0.22	0.20	0.21	0.0178	0.0130
4	0.17	0.19	0.22	0.22	0.23	0.22	0.20	0.0231	0.0170
5	0.19	0.22	0.24	0.20	0.21	0.19	0.21	0.0194	0.0142
6	0.18	0.18	0.19	0.18	0.22	0.23	0.23	0.0225	0.0165
7	0.23	0.23	0.23	0.21	0.19	0.21	0.21	0.0160	0.0117
8	0.17	0.19	0.21	0.23	0.22	0.23	0.20	0.0240	0.0176
9	0.18	0.24	0.22	0.20	0.23	0.20	0.21	0.0222	0.0163
10	0.24	0.22	0.24	0.23	0.20	0.22	0.22	0.0151	0.0111
11	0.22	0.23	0.23	0.19	0.18	0.20	0.20	0.0213	0.1560
12	0.23	0.21	0.22	0.22	0.21	0.19	0.21	0.0136	0.0100
13	0.20	0.18	0.19	0.23	0.23	0.21	0.20	0.0206	0.0151
14	0.19	0.24	0.20	0.20	0.20	0.24	0.21	0.0203	0.0149
15	0.24	0.22	0.21	0.21	0.24	0.22	0.22	0.0136	0.0100
16	0.23	0.23	0.22	0.18	0.21	0.19	0.21	0.0209	0.0153
17	0.22	0.22	0.23	0.20	0.23	0.23	0.22	0.0116	0.0085
18	0.20	0.20	0.21	0.22	0.20	0.21	0.21	0.0159	0.0155
19	0.23	0.24	0.20	0.19	0.22	0.22	0.19	0.0186	0.0136
20	0.22	0.23	0.22	0.24	0.23	0.20	0.22	0.0136	0.0100
21	0.21	0.19	0.23	0.23	0.20	0.22	0.21	0.0147	0.0108
22	0.19	0.22	0.20	0.22	0.22	0.23	0.21	0.0151	0.0111
23	0.17	0.20	0.22	0.23	0.23	0.20	0.20	0.0231	0.0170
24	0.18	0.22	0.19	0.20	0.20	0.22	0.20	0.0160	0.0117
25	0.22	0.24	0.23	0.23	0.22	0.23	0.22	0.0146	0.0107
26	0.24	0.21	0.22	0.19	0.19	0.20	0.20	0.0194	0.0142
27	0.20	0.22	0.21	0.21	0.21	0.22	0.21	0.0152	0.0111
28	0.19	0.19	0.19	0.20	0.18	0.19	0.19	0.0136	0.0100
29	0.23	0.18	0.22	0.22	0.20	0.23	0.21	0.0196	0.0144
30	0.21	0.22	0.20	0.19	0.19	0.20	0.20	0.0116	0.0085
36	0.20	0.23	0.22	0.23	0.22	0.20	0.21	0.0136	0.0100
42	0.21	0.21	0.19	0.21	0.21	0.23	0.21	0.0126	0.0557
48	0.19	0.22	0.20	0.23	0.23	0.22	0.22	0.0164	0.0120
54	0.20	0.24	0.21	0.22	0.22	0.20	0.20	0.0151	0.0111
60	0.22	0.20	0.18	0.20	0.19	0.18	0.19	0.0151	0.0111
66	0.21	0.23	0.21	0.21	0.23	0.22	0.21	0.0138	0.0101
72	0.20	0.22	0.22	0.19	0.20	0.20	0.20	0.0122	0.0089
78	0.22	0.21	0.20	0.22	0.22	0.19	0.21	0.0136	0.0100
84	0.20	0.23	0.23	0.20	0.21	0.21	0.21	0.0136	0.0100
90	0.18	0.20	0.22	0.19	0.19	0.22	0.20	0.0167	0.0122
96	0.20	0.19	0.20	0.20	0.20	0.20	0.20	0.0152	0.0112
102	0.20	0.21	0.21	0.20	0.20	0.21	0.20	0.0143	0.0111

MERCURY-PATTERN I: RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF MULLET L. MACROLEPIS THAT LIVED TILL 96 h AT 96 h Lc 50 LEVEL

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.E.	S.E.
1	0.22	0.21	0.20	0.22	0.20	0.21	0.21	0.0890	0.0650
2	0.19	0.22	0.18	0.20	0.19	0.22	0.20	0.0167	0.0122
3	0.20	0.20	0.19	0.23	0.23	0.20	0.21	0.0132	0.0126
4	0.17	0.21	0.22	0.20	0.22	0.22	0.20	0.0148	0.0134
5	0.19	0.23	0.21	0.21	0.23	0.19	0.20	0.0178	0.0131
6	0.20	0.20	0.18	0.22	0.20	0.21	0.19	0.0132	0.0971
7	0.35	0.29	0.25	0.34	0.25	0.29	0.29	0.0228	0.0167
8	0.29	0.31	0.30	0.40	0.28	0.36	0.32	0.0467	0.0343
9	0.31	0.29	0.28	0.44	0.24	0.40	0.33	0.0768	0.0528
10	0.29	0.27	0.32	0.44	0.25	0.33	0.31	0.0674	0.0496
11	0.33	0.25	0.27	0.40	0.33	0.27	0.30	0.0560	0.0412
12	0.34	0.27	0.29	0.40	0.26	0.43	0.33	0.0750	0.0552
13	0.31	0.26	0.25	0.35	0.29	0.33	0.29	0.0392	0.0288
14	0.31	0.28	0.27	0.31	0.26	0.31	0.29	0.0228	0.0167
15	0.38	0.30	0.26	0.42	0.31	0.34	0.33	0.0578	0.0425
16	0.31	0.26	0.25	0.35	0.24	0.32	0.28	0.0444	0.0326
17	0.38	0.31	0.27	0.26	0.29	0.33	0.30	0.0441	0.0324
18	0.29	0.29	0.26	0.29	0.24	0.29	0.27	0.0216	0.0158
19	0.31	0.26	0.29	0.40	0.26	0.24	0.29	0.0598	0.0425
20	0.35	0.27	0.27	0.42	0.33	0.32	0.32	0.0560	0.0412
21	0.33	0.38	0.25	0.40	0.29	0.25	0.32	0.0643	0.0399
22	0.31	0.35	0.29	0.40	0.24	0.38	0.33	0.0612	0.0450
23	0.29	0.29	0.26	0.42	0.25	0.27	0.29	0.0628	0.0462
24	0.26	0.26	0.27	0.38	0.23	0.26	0.27	0.0524	0.0119
25	0.29	0.27	0.25	0.33	0.29	0.29	0.30	0.0265	0.0195
26	0.26	0.25	0.24	0.31	0.24	0.35	0.29	0.0450	0.0331
27	0.28	0.26	0.25	0.33	0.30	0.29	0.30	0.0288	0.0211
28	0.26	0.27	0.24	0.32	0.26	0.26	0.28	0.0271	0.0125
29	0.27	0.24	0.28	0.33	0.31	0.25	0.30	0.0209	0.0153
30	0.29	0.25	0.26	0.30	0.27	0.25	0.28	0.0209	0.0153
36	0.23	0.24	0.23	0.33	0.24	0.23	0.25	0.0394	0.0290
42	0.24	0.25	0.23	0.36	0.25	0.27	0.26	0.0446	0.0350
48	0.26	0.27	0.22	0.37	0.23	0.22	0.27	0.0570	0.0419
54	0.27	0.25	0.24	0.31	0.26	0.31	0.27	0.0301	0.0221
60	0.25	0.27	0.23	0.35	0.33	0.33	0.29	0.0496	0.0336
66	0.27	0.26	0.22	0.40	0.28	0.38	0.30	0.0716	0.0527
72	0.25	0.25	0.24	0.42	0.26	0.35	0.29	0.0734	0.0540
78	0.26	0.26	0.23	0.39	0.27	0.33	0.29	0.0589	0.0433
84	0.23	0.27	0.26	0.38	0.24	0.35	0.28	0.0441	0.0324
90	0.24	0.24	0.29	0.34	0.22	0.29	0.27	0.0447	0.0329
96	0.22	0.20	0.25	0.24	0.20	0.33	0.24	0.0485	0.0366
102	0.24	0.24	0.26	0.35	0.23	0.32	0.27	0.0467	0.0366

TABLE 48 RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF CONTROL MULLET L. MACROLEPIS DURING 96 h CONTINUOUS FLOW BIOASSAY TEST

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
1	0.22	0.21	0.20	0.22	0.23	0.22	0.21	0.0103	0.0075
2	0.20	0.18	0.19	0.21	0.21	0.20	0.19	0.0116	0.0085
3	0.22	0.22	0.17	0.23	0.20	0.21	0.20	0.0213	0.0156
4	0.24	0.18	0.18	0.22	0.22	0.20	0.20	0.0242	0.0178
5	0.21	0.22	0.20	0.22	0.23	0.21	0.21	0.0104	0.0076
6	0.20	0.20	0.19	0.19	0.22	0.19	0.19	0.0116	0.0085
7	0.22	0.18	0.21	0.21	0.38	0.22	0.24	0.0717	0.0527
8	0.36	0.23	0.31	0.42	0.29	0.28	0.31	0.0665	0.0489
9	0.34	0.32	0.26	0.40	0.42	0.31	0.34	0.0594	0.0393
10	0.31	0.31	0.28	0.42	0.34	0.28	0.32	0.0524	0.0385
11	0.33	0.26	0.25	0.40	0.31	0.26	0.30	0.0577	0.0424
12	0.32	0.23	0.30	0.33	0.26	0.25	0.28	0.0407	0.0299
13	0.26	0.25	0.28	0.32	0.24	0.27	0.27	0.0282	0.0207
14	0.24	0.31	0.26	0.33	0.31	0.28	0.28	0.0343	0.0252
15	0.29	0.34	0.33	0.28	0.24	0.27	0.29	0.0376	0.0278
16	0.28	0.31	0.27	0.33	0.26	0.30	0.29	0.0403	0.0296
17	0.38	0.26	0.26	0.33	0.28	0.25	0.28	0.0512	0.0376
18	0.35	0.27	0.24	0.31	0.26	0.28	0.29	0.0393	0.0289
19	0.22	0.23	0.35	0.24	0.24	0.23	0.25	0.0487	0.0358
20	0.33	0.22	0.38	0.29	0.25	0.24	0.28	0.0584	0.0429
21	0.29	0.31	0.31	0.26	0.23	0.25	0.26	0.0333	0.0244
22	0.31	0.26	0.38	0.24	0.24	0.23	0.27	0.0581	0.0427
23	0.22	0.24	0.27	0.22	0.26	0.24	0.24	0.0204	0.0591
24	0.24	0.22	0.24	0.23	0.22	0.24	0.23	0.0204	0.0153
25	0.25	0.29	0.28	0.29	0.26	0.27	0.27	0.0163	0.0119
26	0.23	0.25	0.24	0.27	0.27	0.24	0.24	0.0136	0.0100
27	0.26	0.23	0.25	0.24	0.26	0.23	0.25	0.0137	0.0100
28	0.25	0.20	0.23	0.25	0.25	0.24	0.23	0.0196	0.0100
29	0.24	0.21	0.22	0.23	0.24	0.22	0.22	0.0121	0.0089
30	0.23	0.21	0.21	0.24	0.22	0.23	0.22	0.0121	0.0089
36	0.22	0.23	0.22	0.23	0.24	0.23	0.22	0.0124	0.0087
42	0.23	0.20	0.20	0.23	0.23	0.21	0.21	0.0150	0.0110
48	0.21	0.24	0.22	0.24	0.23	0.22	0.22	0.0121	0.0089
54	0.26	0.22	0.28	0.24	0.22	0.23	0.23	0.0183	0.0134
60	0.24	0.22	0.23	0.23	0.24	0.22	0.23	0.0171	0.0132
66	0.22	0.22	0.23	0.23	0.22	0.22	0.22	0.0165	0.0143
72	0.24	0.23	0.24	0.21	0.23	0.22	0.22	0.0116	0.0085
78	0.21	0.22	0.20	0.23	0.22	0.21	0.21	0.0104	0.0076
84	0.22	0.23	0.21	0.23	0.22	0.22	0.22	0.0117	0.0152
90	0.20	0.19	0.22	0.23	0.20	0.22	0.21	0.0154	0.0113
96	0.18	0.20	0.22	0.20	0.22	0.20	0.20	0.0150	0.0110
102	0.19	0.21	0.20	0.21	0.21	0.21	0.21	0.0160	0.0112

MERCURY-PATTERN II: RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF MULLET L. MACROLEPIS THAT DIED AT THE END OF 96 h AT 96 h Lc 50 LEVEL

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
1	0.24	0.23	0.22	0.22	0.20	0.21	0.22	0.0141	0.0103
2	0.20	0.22	0.23	0.18	0.19	0.20	0.20	0.0186	0.0136
3	0.17	0.18	0.18	0.19	0.21	0.22	0.19	0.0194	0.0142
4	0.19	0.21	0.20	0.20	0.24	0.20	0.17	0.0231	0.0170
5	0.22	0.22	0.20	0.23	0.22	0.21	0.21	0.0103	0.0075
6	0.24	0.23	0.22	0.21	0.22	0.22	0.22	0.0103	0.0075
7	0.23	0.21	0.23	0.19	0.19	0.20	0.20	0.0183	0.0134
8	0.22	0.24	0.20	0.23	0.22	0.22	0.22	0.0132	0.0097
9	0.17	0.22	0.22	0.18	0.18	0.20	0.18	0.0216	0.0158
10	0.22	0.17	0.17	0.17	0.19	0.18	0.18	0.0196	0.0144
11	0.17	0.24	0.22	0.21	0.20	0.23	0.21	0.0252	0.0185
12	0.17	0.20	0.20	0.23	0.21	0.22	0.20	0.0207	0.0152
13	0.19	0.20	0.20	0.20	0.23	0.24	0.21	0.0213	0.0147
14	0.17	0.18	0.17	0.19	0.20	0.21	0.19	0.0163	0.0119
15	0.20	0.20	0.17	0.22	0.18	0.19	0.19	0.0175	0.0128
16	0.21	0.24	0.18	0.18	0.23	0.22	0.21	0.0252	0.0185
17	0.22	0.23	0.23	0.20	0.19	0.20	0.21	0.0157	0.0115
18	0.18	0.22	0.18	0.21	0.20	0.21	0.20	0.0167	0.0122
19	0.24	0.24	0.20	0.17	0.23	0.18	0.21	0.0309	0.0227
20	0.22	0.23	0.20	0.22	0.19	0.22	0.21	0.0147	0.0188
21	0.24	0.24	0.21	0.20	0.23	0.20	0.22	0.0189	0.0139
22	0.24	0.22	0.22	0.23	0.22	0.23	0.23	0.0189	0.0096
23	0.20	0.23	0.22	0.23	0.22	0.21	0.22	0.0116	0.0085
24	0.19	0.21	0.17	0.22	0.18	0.19	0.19	0.0186	0.0136
25	0.17	0.18	0.18	0.18	0.19	0.17	0.18	0.0196	0.0154
26	0.21	0.19	0.17	0.18	0.20	0.21	0.19	0.0163	0.0119
27	0.22	0.24	0.23	0.20	0.21	0.20	0.21	0.0163	0.0119
28	0.17	0.23	0.22	0.18	0.18	0.20	0.20	0.0242	0.0104
29	0.17	0.20	0.17	0.17	0.22	0.22	0.22	0.0246	0.0108
30	0.23	0.22	0.20	0.20	0.17	0.19	0.20	0.0242	0.0114
36	0.21	0.18	0.17	0.22	0.22	0.21	0.20	0.0213	0.0230
42	0.20	0.20	0.22	0.20	0.20	0.22	0.22	0.0103	0.0075
48	0.20	0.22	0.22	0.21	0.22	0.20	0.21	0.0121	0.0089
54	0.20	0.23	0.21	0.22	0.21	0.22	0.20	0.0104	0.0076
60	0.22	0.20	0.20	0.22	0.22	0.22	0.21	0.0103	0.0075
66	0.20	0.21	0.20	0.21	0.21	0.20	0.20	0.0105	0.0074
72	0.21	0.22	0.20	0.22	0.18	0.21	0.20	0.0150	0.0110
78	0.23	0.20	0.22	0.20	0.20	0.23	0.21	0.0150	0.0110
84	0.20	0.22	0.18	0.17	0.18	0.22	0.19	0.0021	0.0158
90	0.22	0.18	0.17	0.21	0.19	0.20	0.20	0.0187	0.0137
96	0.19	0.20	0.18	0.19	0.20	0.17	0.18	0.0116	0.0085
102	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 49 RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF CONTROL MULLET *L. MACROLEPIS* DURING 96 h CONTINUOUS FLOW BIOASSAY TEST

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
1	0.22	0.20	0.24	0.21	0.17	0.22	0.21	0.0236	0.0173
2	0.20	0.22	0.22	0.19	0.22	0.18	0.20	0.0176	0.1295
3	0.22	0.20	0.23	0.20	0.19	0.19	0.20	0.0164	0.0120
4	0.23	0.24	0.21	0.23	0.21	0.21	0.22	0.0132	0.0097
5	0.20	0.22	0.20	0.22	0.23	0.23	0.21	0.0136	0.0100
6	0.22	0.20	0.23	0.22	0.20	0.20	0.22	0.0132	0.0097
7	0.21	0.23	0.21	0.20	0.21	0.22	0.21	0.0103	0.0075
8	0.23	0.19	0.23	0.23	0.24	0.19	0.22	0.0222	0.0163
9	0.20	0.22	0.20	0.20	0.22	0.17	0.20	0.0183	0.0134
10	0.22	0.20	0.23	0.22	0.23	0.20	0.21	0.0136	0.0100
11	0.23	0.19	0.21	0.23	0.20	0.21	0.21	0.0160	0.0117
12	0.20	0.24	0.24	0.20	0.17	0.22	0.21	0.0271	0.0199
13	0.24	0.22	0.22	0.24	0.22	0.24	0.23	0.0109	0.0080
14	0.19	0.24	0.20	0.21	0.21	0.21	0.21	0.0167	0.0122
15	0.21	0.21	0.19	0.23	0.23	0.19	0.21	0.0189	0.0139
16	0.20	0.19	0.21	0.19	0.21	0.23	0.20	0.0151	0.0111
17	0.18	0.23	0.23	0.24	0.24	0.22	0.22	0.0225	0.0165
18	0.22	0.22	0.20	0.22	0.20	0.24	0.21	0.0150	0.0110
19	0.20	0.24	0.18	0.18	0.23	0.21	0.20	0.0250	0.0184
20	0.23	0.21	0.22	0.24	0.21	0.22	0.22	0.0116	0.0085
21	0.22	0.23	0.23	0.23	0.20	0.19	0.21	0.0175	0.0128
22	0.19	0.22	0.19	0.19	0.24	0.20	0.20	0.0207	0.0152
23	0.20	0.24	0.22	0.21	0.21	0.22	0.21	0.0136	0.0100
24	0.18	0.21	0.20	0.23	0.23	0.19	0.22	0.0206	0.0151
25	0.23	0.22	0.23	0.20	0.19	0.21	0.20	0.0163	0.0119
26	0.17	0.20	0.22	0.22	0.22	0.23	0.21	0.0219	0.0161
27	0.23	0.18	0.20	0.24	0.24	0.20	0.21	0.0250	0.0184
28	0.19	0.21	0.23	0.22	0.19	0.18	0.20	0.0176	0.0129
29	0.21	0.24	0.23	0.20	0.23	0.18	0.21	0.0225	0.0165
30	0.20	0.22	0.20	0.21	0.19	0.22	0.20	0.0121	0.0089
36	0.19	0.23	0.22	0.23	0.21	0.20	0.21	0.0163	0.0119
42	0.22	0.22	0.20	0.21	0.22	0.23	0.22	0.0103	0.0075
48	0.20	0.19	0.19	0.22	0.23	0.19	0.20	0.0175	0.0128
54	0.21	0.20	0.23	0.23	0.19	0.22	0.21	0.0163	0.0119
60	0.23	0.22	0.22	0.24	0.24	0.21	0.23	0.0121	0.0089
66	0.21	0.19	0.20	0.22	0.21	0.23	0.21	0.0141	0.0103
72	0.22	0.21	0.21	0.21	0.22	0.19	0.21	0.0109	0.0082
78	0.20	0.20	0.23	0.20	0.19	0.22	0.20	0.0150	0.0110
84	0.21	0.17	0.21	0.23	0.20	0.20	0.20	0.0196	0.0144
90	0.20	0.19	0.22	0.22	0.18	0.18	0.19	0.0183	0.0134
96	0.19	0.18	0.20	0.20	0.17	0.20	0.19	0.0126	0.0092
102	0.20	0.18	0.21	0.21	0.18	0.20	0.20	0.0136	0.0100

CADMIUM-PATTERN I: RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF MULLET *L. MACROLEPIS* THAT LIVED TILL 96 h AT 96 h Lc 50 LEVEL

NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
0.23	0.22	0.22	0.23	0.20	0.19	0.21	0.0164	0.0120
0.20	0.24	0.23	0.24	0.22	0.18	0.22	0.0240	0.0176
0.22	0.23	0.20	0.23	0.19	0.22	0.21	0.0164	0.0113
0.23	0.22	0.23	0.24	0.23	0.21	0.23	0.0103	0.0758
0.20	0.24	0.19	0.25	0.21	0.23	0.22	0.0236	0.0173
0.22	0.20	0.22	0.23	0.24	0.22	0.22	0.0132	0.0097
0.24	0.32	0.24	0.26	0.23	0.28	0.26	0.0337	0.0248
0.26	0.26	0.31	0.29	0.25	0.31	0.28	0.0268	0.0197
0.27	0.33	0.38	0.32	0.24	0.26	0.32	0.0508	0.0373
0.31	0.31	0.24	0.26	0.28	0.24	0.27	0.0320	0.0235
0.26	0.26	0.35	0.28	0.27	0.28	0.28	0.0338	0.0248
0.28	0.24	0.38	0.25	0.25	0.29	0.28	0.0519	0.0382
0.25	0.27	0.35	0.29	0.30	0.26	0.29	0.0361	0.0265
0.27	0.26	0.36	0.27	0.28	0.27	0.30	0.0372	0.0273
0.28	0.28	0.31	0.25	0.29	0.31	0.29	0.0225	0.0165
0.26	0.25	0.35	0.33	0.26	0.29	0.29	0.0250	0.0125
0.29	0.26	0.24	0.29	0.28	0.31	0.27	0.0248	0.0182
0.31	0.36	0.38	0.31	0.29	0.26	0.32	0.0444	0.0323
0.27	0.28	0.33	0.30	0.31	0.25	0.29	0.0289	0.0212
0.24	0.27	0.34	0.24	0.26	0.27	0.27	0.0368	0.0270
0.26	0.24	0.31	0.26	0.28	0.33	0.28	0.0340	0.0250
0.25	0.27	0.23	0.25	0.26	0.24	0.25	0.0141	0.0103
0.33	0.26	0.24	0.24	0.29	0.25	0.27	0.0354	0.0260
0.30	0.28	0.36	0.27	0.25	0.35	0.30	0.0393	0.0284
0.28	0.27	0.33	0.26	0.29	0.29	0.28	0.0242	0.0178
0.24	0.24	0.31	0.24	0.30	0.31	0.27	0.0366	0.0269
0.25	0.26	0.32	0.27	0.28	0.26	0.27	0.0250	0.0184
0.30	0.25	0.35	0.29	0.26	0.25	0.28	0.0388	0.0285
0.26	0.27	0.28	0.25	0.24	0.23	0.25	0.0141	0.0123
0.24	0.25	0.24	0.23	0.25	0.25	0.24	0.0215	0.0173
0.31	0.31	0.35	0.24	0.25	0.23	0.28	0.0483	0.0355
0.29	0.30	0.36	0.27	0.26	0.24	0.29	0.0360	0.0264
0.26	0.24	0.25	0.20	0.29	0.27	0.25	0.0306	0.0225
0.35	0.26	0.34	0.35	0.24	0.24	0.29	0.0553	0.0407
0.33	0.24	0.31	0.31	0.26	0.25	0.28	0.0377	0.0277
0.26	0.28	0.38	0.37	0.24	0.23	0.29	0.0656	0.0482
0.29	0.25	0.26	0.25	0.27	0.24	0.26	0.0178	0.0131
0.28	0.27	0.29	0.29	0.24	0.28	0.28	0.0178	0.0131
0.25	0.24	0.25	0.24	0.26	0.23	0.25	0.0104	0.0076
0.22	0.25	0.31	0.30	0.27	0.26	0.27	0.0331	0.0243
0.20	0.23	0.26	0.24	0.24	0.23	0.23	0.0196	0.0144
0.24	0.25	0.26	0.25	0.25	0.23	0.24	0.0103	0.0017

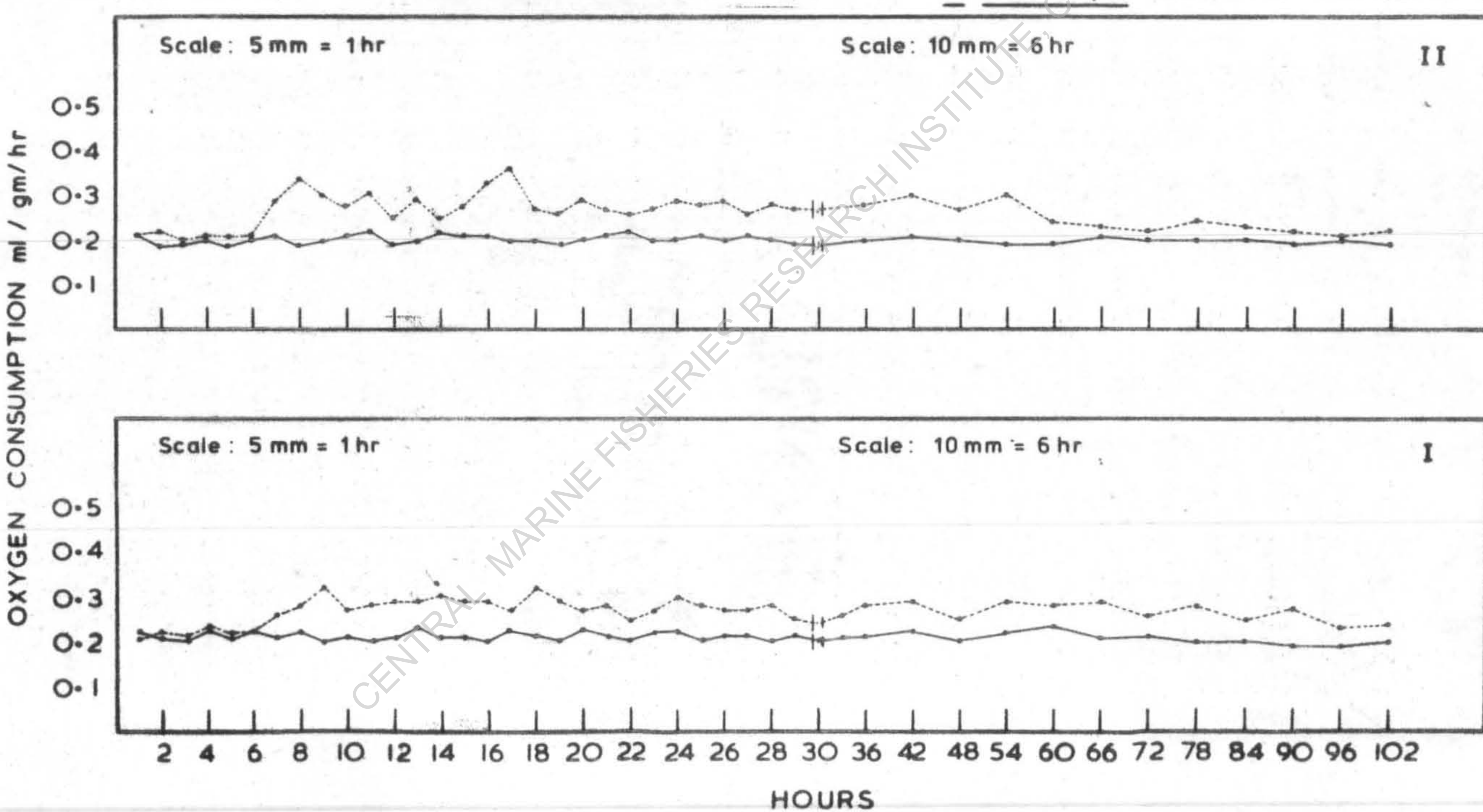
TABLE 50 RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF CONTROL MULLET L. MACROLEPIS DURING 96 h CONTINUOUS FLOW BIOASSAY TEST

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
1	0.20	0.22	0.21	0.21	0.20	0.24	0.21	0.0150	0.0110
2	0.19	0.18	0.19	0.20	0.21	0.17	0.19	0.0141	0.0103
3	0.18	0.21	0.18	0.19	0.23	0.20	0.19	0.0194	0.0142
4	0.21	0.19	0.20	0.22	0.20	0.18	0.20	0.0141	0.0103
5	0.18	0.20	0.19	0.18	0.24	0.20	0.19	0.0222	0.0163
6	0.20	0.18	0.23	0.20	0.20	0.19	0.20	0.0167	0.0122
7	0.21	0.19	0.22	0.22	0.21	0.22	0.21	0.0116	0.0085
8	0.17	0.18	0.23	0.21	0.17	0.18	0.19	0.0244	0.0179
9	0.19	0.17	0.21	0.23	0.22	0.21	0.20	0.0216	0.0158
10	0.20	0.22	0.30	0.20	0.24	0.20	0.21	0.0179	0.0131
11	0.18	0.23	0.22	0.21	0.21	0.24	0.22	0.0207	0.0152
12	0.17	0.19	0.20	0.19	0.20	0.22	0.19	0.0164	0.0120
13	0.19	0.20	0.20	0.21	0.22	0.20	0.20	0.0103	0.0075
14	0.21	0.21	0.22	0.21	0.23	0.24	0.22	0.0126	0.0092
15	0.20	0.22	0.23	0.20	0.20	0.23	0.21	0.0150	0.0110
16	0.18	0.23	0.24	0.22	0.22	0.20	0.21	0.0216	0.0158
17	0.19	0.19	0.20	0.22	0.23	0.19	0.20	0.0175	0.0128
18	0.20	0.17	0.21	0.21	0.22	0.23	0.20	0.0197	0.0145
19	0.19	0.18	0.21	0.19	0.19	0.23	0.19	0.0183	0.0134
20	0.20	0.22	0.18	0.21	0.20	0.22	0.20	0.0151	0.0111
21	0.17	0.23	0.20	0.19	0.23	0.24	0.21	0.0275	0.0202
22	0.22	0.20	0.23	0.21	0.24	0.22	0.22	0.0141	0.0103
23	0.24	0.22	0.20	0.20	0.18	0.24	0.20	0.0242	0.0178
24	0.17	0.18	0.24	0.18	0.23	0.23	0.20	0.0314	0.0231
25	0.18	0.21	0.22	0.20	0.24	0.24	0.21	0.0234	0.0172
26	0.19	0.22	0.19	0.20	0.22	0.22	0.20	0.0160	0.0117
27	0.19	0.19	0.21	0.20	0.20	0.24	0.21	0.0187	0.0137
28	0.22	0.19	0.17	0.21	0.21	0.23	0.20	0.0216	0.0158
29	0.20	0.20	0.21	0.18	0.19	0.20	0.19	0.0183	0.0134
30	0.18	0.19	0.18	0.20	0.19	0.20	0.19	0.0172	0.0126
36	0.22	0.18	0.17	0.21	0.21	0.23	0.20	0.0233	0.0171
42	0.20	0.20	0.22	0.23	0.22	0.22	0.21	0.0122	0.0089
48	0.19	0.17	0.20	0.21	0.19	0.20	0.20	0.0136	0.0010
54	0.22	0.18	0.17	0.21	0.20	0.19	0.19	0.0187	0.0137
60	0.20	0.20	0.18	0.19	0.18	0.21	0.19	0.0132	0.0097
66	0.20	0.19	0.22	0.22	0.23	0.20	0.21	0.0154	0.0113
72	0.20	0.20	0.21	0.22	0.20	0.23	0.20	0.0132	0.0097
78	0.22	0.21	0.19	0.22	0.17	0.19	0.20	0.0219	0.0161
84	0.17	0.20	0.19	0.20	0.22	0.22	0.20	0.0244	0.0179
90	0.18	0.18	0.22	0.19	0.19	0.18	0.19	0.0147	0.0108
96	0.20	0.17	0.18	0.20	0.22	0.21	0.20	0.0194	0.0014
102	0.19	0.19	0.19	0.20	0.20	0.21	0.19	0.0145	0.0106

CADMIUM-PATTERN II: RATE OF OXYGEN CONSUMPTION (ml/gm/h) OF MULLET L. MACROLEPIS THAT DIED AT THE END OF 96 h AT 96 h Lc 50 LEVEL

HOURS	NUMBER OF FISHES (1)	(2)	(3)	(4)	(5)	(6)	MEAN (ml/gm/h)	S.D.	S.E.
1	0.22	0.21	0.22	0.19	0.20	0.19	0.20	0.0137	0.0100
2	0.23	0.22	0.24	0.22	0.23	0.22	0.22	0.0138	0.0101
3	0.20	0.19	0.18	0.20	0.22	0.23	0.20	0.0186	0.0136
4	0.22	0.21	0.17	0.18	0.23	0.22	0.21	0.0242	0.0178
5	0.20	0.22	0.20	0.23	0.20	0.23	0.21	0.0150	0.0110
6	0.19	0.23	0.22	0.22	0.19	0.22	0.21	0.0200	0.0147
7	0.35	0.31	0.24	0.25	0.35	0.24	0.29	0.0532	0.0391
8	0.33	0.27	0.26	0.28	0.35	0.26	0.34	0.0337	0.0248
9	0.36	0.28	0.33	0.23	0.27	0.33	0.30	0.0481	0.0317
10	0.29	0.25	0.25	0.27	0.37	0.26	0.28	0.0457	0.0336
11	0.31	0.26	0.29	0.31	0.39	0.29	0.31	0.0403	0.0296
12	0.35	0.25	0.27	0.29	0.36	0.24	0.25	0.0508	0.0373
13	0.27	0.26	0.24	0.34	0.30	0.33	0.29	0.0400	0.0294
14	0.26	0.24	0.25	0.25	0.24	0.29	0.25	0.0147	0.0137
15	0.31	0.26	0.24	0.30	0.35	0.24	0.28	0.0628	0.0462
16	0.32	0.24	0.22	0.24	0.38	0.27	0.33	0.0608	0.0447
17	0.33	0.33	0.25	0.29	0.29	0.33	0.36	0.0326	0.0239
18	0.31	0.26	0.24	0.28	0.26	0.24	0.27	0.0266	0.0195
19	0.35	0.25	0.22	0.29	0.24	0.26	0.26	0.0462	0.0340
20	0.31	0.29	0.29	0.31	0.24	0.29	0.29	0.0256	0.0188
21	0.35	0.25	0.25	0.27	0.22	0.26	0.27	0.0441	0.0324
22	0.36	0.27	0.23	0.29	0.23	0.22	0.26	0.0531	0.0390
23	0.35	0.29	0.24	0.24	0.25	0.23	0.27	0.0458	0.0337
24	0.40	0.25	0.31	0.26	0.29	0.25	0.29	0.0575	0.0423
25	0.38	0.27	0.26	0.28	0.27	0.25	0.29	0.0476	0.0350
26	0.40	0.25	0.29	0.24	0.25	0.29	0.29	0.0595	0.0437
27	0.35	0.27	0.26	0.24	0.24	0.25	0.26	0.0427	0.0314
28	0.38	0.29	0.29	0.26	0.24	0.25	0.28	0.0508	0.0373
29	0.29	0.26	0.35	0.24	0.25	0.26	0.27	0.0403	0.0296
30	0.35	0.25	0.31	0.26	0.23	0.24	0.27	0.0467	0.0345
36	0.25	0.32	0.36	0.29	0.21	0.21	0.28	0.0608	0.0447
42	0.31	0.27	0.25	0.30	0.23	0.24	0.30	0.0430	0.0326
48	0.35	0.25	0.29	0.24	0.22	0.27	0.27	0.0460	0.0338
54	0.38	0.30	0.24	0.31	0.31	0.28	0.30	0.0454	0.0337
60	0.24	0.28	0.26	0.24	0.25	0.26	0.24	0.0151	0.0111
66	0.22	0.25	0.27	0.31	0.24	0.23	0.23	0.0326	0.0239
72	0.31	0.26	0.23	0.25	0.25	0.27	0.26	0.0271	0.0199
78	0.23	0.24	0.20	0.22	0.27	0.23	0.24	0.0231	0.0170
84	0.25	0.25	0.22	0.23	0.22	0.24	0.23	0.0137	0.0100
90	0.28	0.24	0.22	0.23	0.23	0.22	0.22	0.0225	0.0165
96	0.20	0.19	0.21	0.18	0.22	0.23	0.21	0.0187	0.0137
102	0.23	0.18	0.21	0.21	0.23	0.23	0.22	0.0197	0.0145

FIG. 52 EFFECT OF CADMIUM ON RESPIRATION OF L macrolepis SHOWING PATTERN I & II



In the case of mullets exposed to cadmium (2940 ppb), scales with blood stains were seen to peel off from the body (Fig.49). The caudal fin margin was eroded. Due to erosion of fin rays, the fin appeared circular in shape (Fig. 50). The fin membranes were sheared and fin rays were seen as individual structure. Such fin erosion diseases are known to alter the swimming behaviour of fishes and place them in a disadvantageous postion which could threaten their very survival in the environment (Lingaraja *et al.*, 1979).

3.4.4 Respiratory responses of mullet, *Liza macrolepis* (Smith) at 96 h Lc 50 levels of mercury and cadmium

In the present study, respiratory response of the fingerlings of mullets, *Liza macrolepis* (Smith) in the length range of 80-85 mm (weight ranged from 5.0 to 5.5 gm) were recorded. Experiments were conducted for a period of 96 h at 96 h Lc 50 levels of mercury (360 ppb) and cadmium (2940 ppb). Concurrently, control experiments were conducted. The data are presented in Tables 47 to 50.

Fishes were acclimated for a period of six hours in animal chambers in order to reduce effects if any due to handling. Hourly determinations of oxygen uptake were then carried out for the first 24 h period and thereafter recordings were made once in every six hour. Each point in the graph (Figs. 51 & 52) represents the average oxygen consumption for a total number of six fishes. It may be seen that in healthy untreated fishes there was no tidal or diurnal rhythm in the respiratory response. The rate of oxygen consumption varied from 0.17 to 0.24 ml/gm/h during the 96 h experimental period.

After obtaining data on oxygen uptake by healthy fishes for a period of 6 hrs, estuarine water (S 15‰.) containing 360 ppb of mercury was allowed to flush the animal chambers. After a period of one hour the rate of oxygen consumption was assessed. Following the method of O'Hara (1971) data relating to fishes that lived the entire 96 h period of experiment and fishes that died at the end of 96 h period was considered for the purpose of statistical treatment. Prior to mercury treatment the oxygen level ranged from 0.17 to 0.24 ml/gm/h, the average being 0.21 ml/gm/h.

When fishes are exposed to mercury, the rate of oxygen uptake was significantly affected. It may be seen from the graph that immediately after exposure the rate of oxygen consumption was significantly increased. During this phase the rate of oxygen uptake showed an overall range of 0.38 to 0.44 ml/gm/h. Such a high level was maintained thereafter. When compared to untreated fishes, where the overall oxygen uptake ranged from 0.17 to 0.24 ml/gm/h, in fishes that were exposed to mercury, the rate of oxygen uptake ranged from 0.34 to 0.38 ml/gm/h.

In fishes that lived upto 96 h period, the overall mean rate of oxygen consumption was divided into four sections each consisting a 24 h duration. During the first 24 h period, the rate of oxygen consumption ranged from 0.26 to 0.39 ml/gm/h, the mean being 0.30 ml/gm/h. This initial response in respiratory rate may be treated as an "excitation phase" ((Waiwood and Johansen, 1974; Lingaraja, et al., 1980). During the second 24 h period, the oxygen consumption rate ranged from 0.23 to 0.37 ml/gm/h, the mean being 0.27 ml/gm/h. Continuation of elevated respiratory rates may be indicative of the prolonged "excitation phase". During the third 24 h period, the rate of oxygen consumption did not show much variation. At the end of 96 h period, the oxygen uptake levels decreased and it ranged from 0.23 to 0.32 ml/gm/h, the mean value being 0.27 ml/gm/h. The foregoing results may suggest that the "detoxification phase" may start from the third day after exposure (Premados and Anderson, 1969).

In fishes that died at the end of 96 h period, the presence of "excitation phase" was noted. During this phase, the oxygen uptake was increased to 0.27 ml/gm/h, the range being 0.25 to 0.29 ml/gm/h. However, on the third day, the rate of oxygen consumption was greatly decreased. A low range of 0.21 to 0.23 ml/gm/h was recorded, the mean being 0.21 ml/gm/h Such a decreased level of oxygen uptake may be termed as a "lethal phase" (Spoor, 1946; Lingaraja, et al., 1980). During the third section of 24 h period, the rate of oxygen consumption of the fishes ranged from 0.21 to 0.24 ml/gm/h, the mean value being 0.22 ml/gm/h, thus indicating the continuance of the lethal phase. During the end of 96 h period the rate of oxygen consumption approached the pretreatment level. The rate of oxygen uptake ranged from 0.19 to 0.21 ml/gm/h, the mean being 0.20 ml/gm/h.

Similarly when fishes are exposed to cadmium, the rate of oxygen consumption was increased immediately after exposure and it ranged from 0.35 to 0.40 ml/gm/h, the mean value being 0.32 ml/gm/h.

In fishes that lived upto 96 h period during the excitation phase, the rate of oxygen uptake ranged from 0.27 to 0.31 ml/gm/h, the mean value being 0.28 ml/gm/h. As noted earlier there was a prolongation of 'excitation phase' to the next 24 hour period. The rate of oxygen consumption ranged from 0.23 to 0.30 ml/gm/h, the mean value being 0.26 ml/gm/h. There was no significant change in rate of oxygen consumption during the third quarter. During the end of 96 hour period, the oxygen uptake range decreased significantly and approached near to that of the normal pattern. It may be inferred that the onset of "detoxification phase" may be after a period of 72 h.

Table 51 Results of the statistical inference* (Student's 't' test) for difference between means of controls and treated mullets *L. macrolepis* at 96 h Lc 50 levels of mercury

Hours	Pattern I-Fishes that lived till 96 h	Pattern I[illegible] that died [illegible] the end o[illegible] 96h
	Calculated 't' value	Calcul[illegible] 't' v[illegible]
06	3.92	4.20
12	4.10	4.97
18	3.37	4.98
24	2.25	2.50
30	1.87	3.10
36	2.84	1.29
42	1.97	1.81
48	4.13	2.34
54	4.12	4.11
60	2.79	3.46
66	2.97	2.63
72	3.27	2.30
78	2.89	2.88
84	3.70	1.25
90	2.10	2.28
96	2.18	2.23

*Table 't' value at 5% level 2.23

Table 52 Results of the statistical inference* (Student's 't' test) for difference between means of controls and treated mullets *L. macrolepis* at 96 h Lc 50 levels of cadmium

Hours	Pattern I-Fishes that lived till 96 h Calculated 't' value	Pattern II-Fis[h] that died at t[he] end of 96 h Calculated 't' value
06	2.94	6.27
12	4.09	4.60
18	2.21	2.38
24	7.50	4.66
30	3.33	2.62
36	3.98	2.85
42	3.31	4.00
48	3.01	5.44
54	3.52	3.73
60	3.07	3.50
66	3.20	4.59
72	3.10	2.58
78	5.03	4,04
84	4.24	4.08
90	5.06	3.63
96	7.35	2.28

* Table 't' value at 5% level 2.23

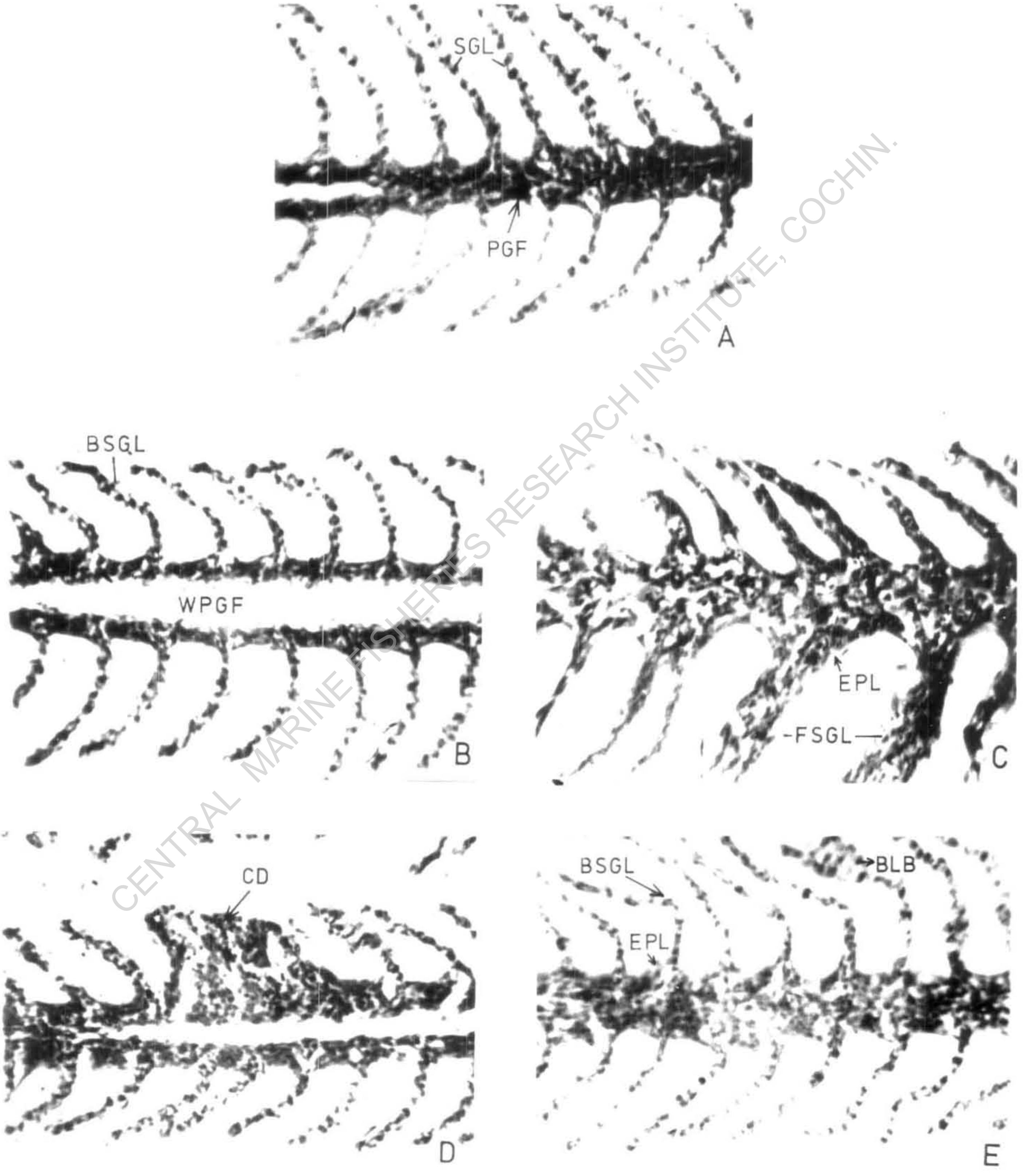
In the case of mullets that died at the end of 96 hour period, the increased oxygen uptake rate prevailed upto 48 hour, the mean value being 0.27 ml/gm/h. The reduced oxygen rates at the end of 96 hour may suggest that fishes are succumbing to the stress condition. In this lethal phase, the oxygen consumption rates further decreased, the mean being 0.22 ml/gm/h.

In order to find out the statistical significance of the variation in oxygen consumption rates between control and treated fishes with mercury and cadmium, the data were analysed by Student''t' test for independent sample observations. The calculated 't' value was compared with the Table 't' value at 5% level of significance for appropriate degree of freedom to identify particular set of mean values differ significantly and the results are presented in Tables 51 & 52.

3.5.0 Histopathological changes in gills, liver and muscle tissues of mullet, *Liza macrolepis* (Smith) when exposed to 96 h Lc 50 levels of mercury and cadmium

When fishes are exposed to heavy metals, a variety of histopathological changes in the gills of fishes such as widening of the primary gill lamellae and interlamellar debris (Brown *et al.*, 1968; Gardner and Yevich, 1970), bending, swelling, hyperplasia and fusion or merging of

FIG. 53



Legend for figures

Fig.53

A - Photomicrograph of the gill tissue (T.S) of the untreated mullet *L. macrolepis* (stained in haematoxlin and counter stained in eosin-10 x 45).

PGF - Primary Gill Filament

SGL - Secondary Gill Lamellae

B & C - Photomicrograph of the gill tissue (T.S) when exposed to mercury - 360 ppb (stained in haematoxlin and counter stained in eosin - 10 x 45).

BSGL - Bending of the Secondary Gill Lamellae

FSGL - Fusion of Secondary Gill Lamellae

EPL - Epithelial Lifting

D & E - Photomicrograph of the gill tissue (T.S) when exposed to cadmium - 2940 ppb (stained in haematoxlin and counter stained in eosin - 10 x 45).

CD - Cell Debris

BSGL - Bending of the Secondary Gill Lamellae

BLB - Blub Formation

EPL - Epithelial lifting

the epithelial cells of the secondary gill lamellae (Skidmore, 1964 and Wobeser, 1975); epithelial lifting of the secondary gill lamellae and epithelial sloughing of the secondary gill lamellae (Skidmore and Tovell, 1972) and accumulation of cell debris in the basal lamellar region (Bilinski and Jonas, 1973), have been observed. In the present study, a few experiments were carried out to assess the nature of histopathological changes consequent to the treatment of mullets, Liza macrolepis (Smith) with mercury and cadmium.

3.5.1 Histology of gill tissue of untreated mullet, L. macrolepis

The histology of a normal fish gill has been reported by several workers (Bevelander, 1935; Bijtel, 1949; Munshi, 1960 and Newstead, 1967). The gill of a healthy mullet of the species, Liza macrolepis (Smith) is made up of a primary gill filament and secondary gill lamellar region interposed by a region commonly called gill arch (Fig. 53 A). The primary gill filament is composed of a central axis made up of epithelial cells, basement membrane, cartilagenous cells and mucous gland cells. The average breadth of the primary gill lamellae measured about 21 μ. The secondary gill lamellar region includes respiratory epithelial cells, blood cells and pillar cells located at the bases of the lamellae. The average breadth of the secondary gill lamellae measured about 5 μ. The gill arch region includes mucous gland cells, epithelial cells and taste buds.

3.5.2 Changes in gill tissue when exposed to mercury

When mullets were exposed to mercury at 96 h Lc 50 level (360 ppb) the gill tissue showed pathological changes such as widening of the primary gill filament. Its width increased from 21 μ to 49 μ (Fig. 53 B). Rupture and loss of cell wall of different types of cells in the primary gill filament region was also observed (Fig. 53 B). Destruction of blood cells, mucous gland cells and epithelial respiratory cells was observed probably due to increased lysosomal activity. There was a proliferation in the number of cells of the cartilagenous axis of the primary gill filament. The secondary gill lamellae enclosing the epithelial cells appeared as bent structures resulting in the curvature of the secondary gill lamellae (Fig. 53 B). The curvature was observed at about a distance of 14 μ from the base. The thickness of the epithelial cells of the secondary gill lamellae was also increased to 10 μ. The epithelial lifting between the junctions of the secondary gill lamellae was significant (Fig. 53 C). Fusion of the epithelial cells of the secondary gill lamellae was also observed (Fig. 53 C).

3.5.3 Changes in gill tissue when exposed to cadmium

In the case of mullets exposed to cadmium at 96 h Lc 50 level (2940 ppb), the thickening of the primary gill filament

FIG. 54

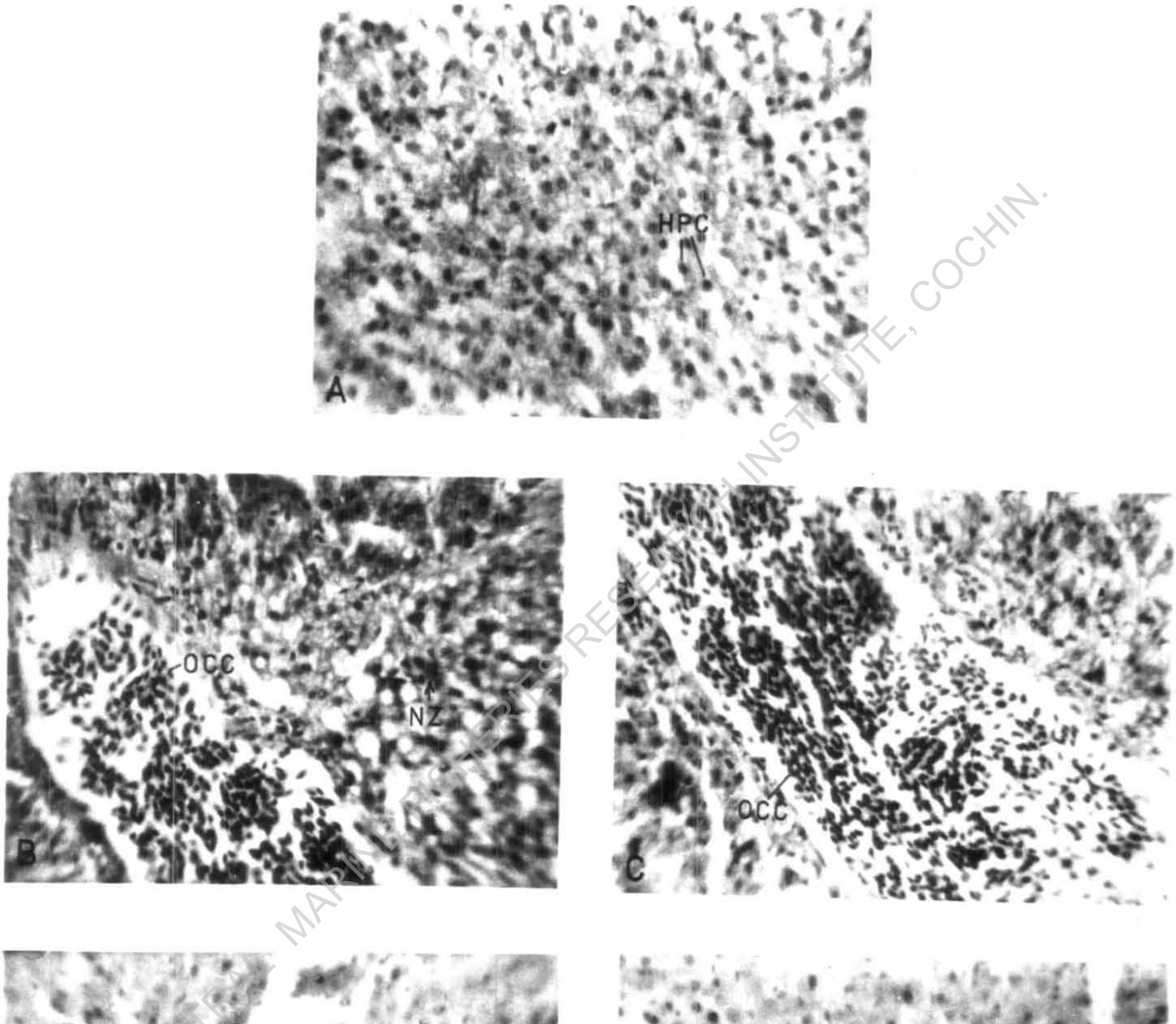


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Fig.54

A - Photomicrograph of the liver tissue (T.S) of the untreated mullet *L. macrolepis* (stained in haematoxlin and counter stained in eosin - 10 x 45).

HPC - Hepatic cells

B & C - Photomicrograph of the liver tissue (T.S) when exposed to mercury - 360 ppb (stained in haematoxlin and counter stained in eosin - 10 x 45)

NZ - Necrosis Zone

OCC - Occlusion of Cells

D & E - Photomicrograph of the liver tissue (T.S) when exposed to cadmium - 2940 ppb (stained in haematoxlin and counter stained in eosin - 10 x 45).

NZ - Necrosis Zone

INFC - Infiltration of Mononuclear Cells was noticed and it measured about 39 μ. Interlamellar cell debris and merging of the epithelial cells of the secondary gill lamellae was observed (Fig. 53 D). Epithelial lifting in the interlamellar junctions of the secondary gill lamellae recalled similar conditions as observed in mullets treated with mercury (Fig. 53 E). Bending of the secondary gill lamellae was seen as curved structures and the curvature was observed at about a distance of 11 μ from the base (Fig. 53 E). The thickness of the epithelial cells of the secondary gill lamellae was found to be 8 μ.

3.5.4 Histology of the liver tissue of untreated mullet, *L. macrolepis*

The liver of control mullet showed compact parenchymal cells and well differenciated portal system. The parenchymal cell vacuolation was smaller. The hepatic cells with cellular outlines were composed of distinct nucleus surrounded by a homogenous cytoplasm (Fig. 54 A).

3.5.5 Changes in liver tissue when exposed to mercury

In the case of mullets exposed to mercury at 96 h Lc 50 level (360 ppb), enlargements of the hepatic cells followed by degenerative changes were observed. Enlargement was found to be 10 μ when compared with the cells of the control fish (3 u). Rupture of the hepatic cell wall and

FIG. 55

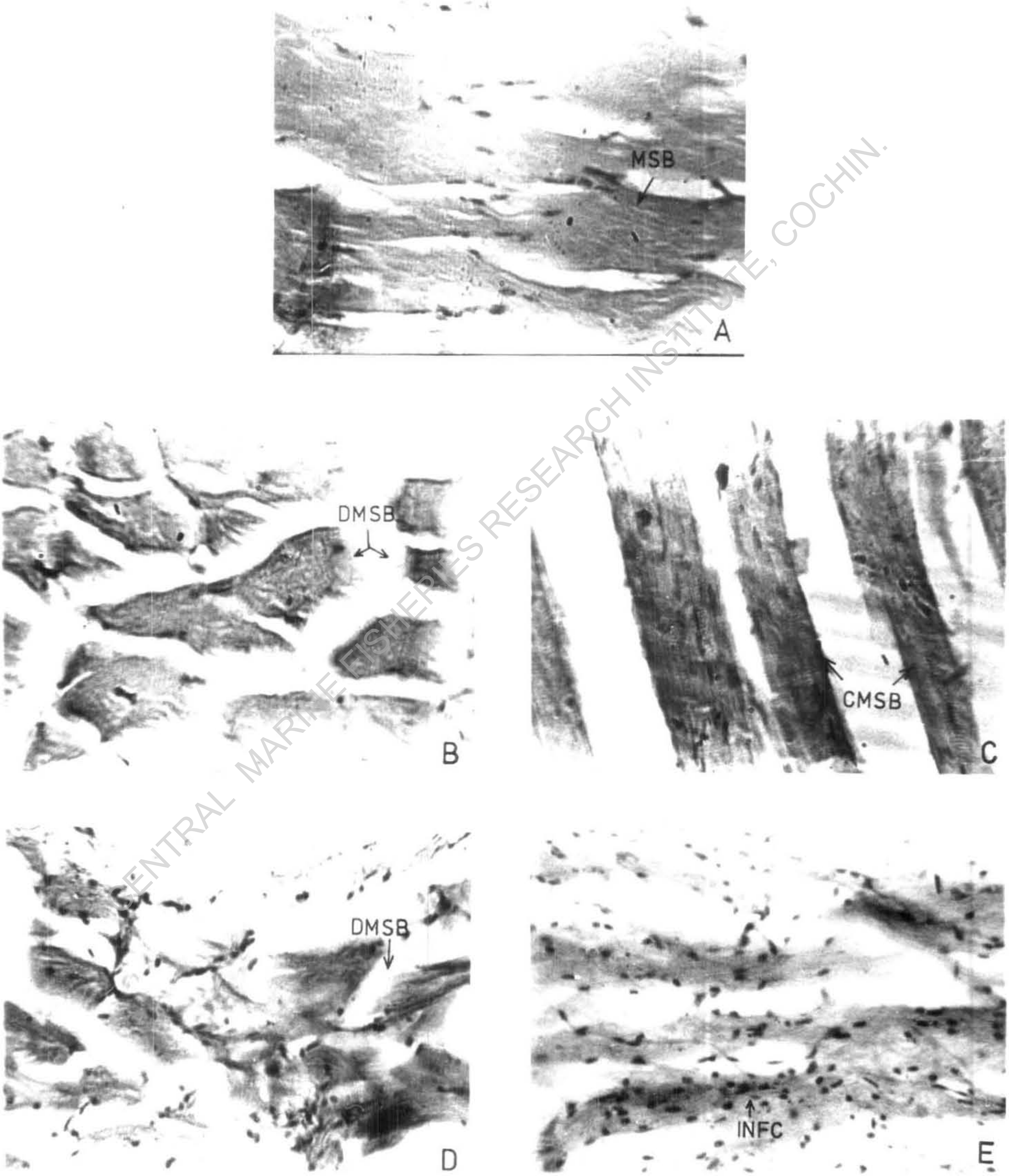

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Fig.55

A - Photomicrograph of the muscle tissue (T.S) of the untreated mullet *L. macrolepis* (stained in haematoxlin and counter stained in eosin)

MSB - Muscle Bundle

B & C - Photomicrograph of the muscle tissue (T.S) when exposed to mercury - 360 ppb (stained in haematoxlin and counter stained in eosin - 10 x 45).

CMBC - Constriction of the Muscle Bundles

DMSB - Discontinuity of the Muscle Bundles

D & E - Photomicrograph of the muscle tissue (T.S) when exposed to cadmium - 2940 ppb (stained in haematoxlin and counter stained in eosin - 10 x 45).

DMSB - Discontinuity of the Muscle Bundles

INFC - Infiltrated Cells

3.5.8 Changes in muscle tissue when exposed to mercury

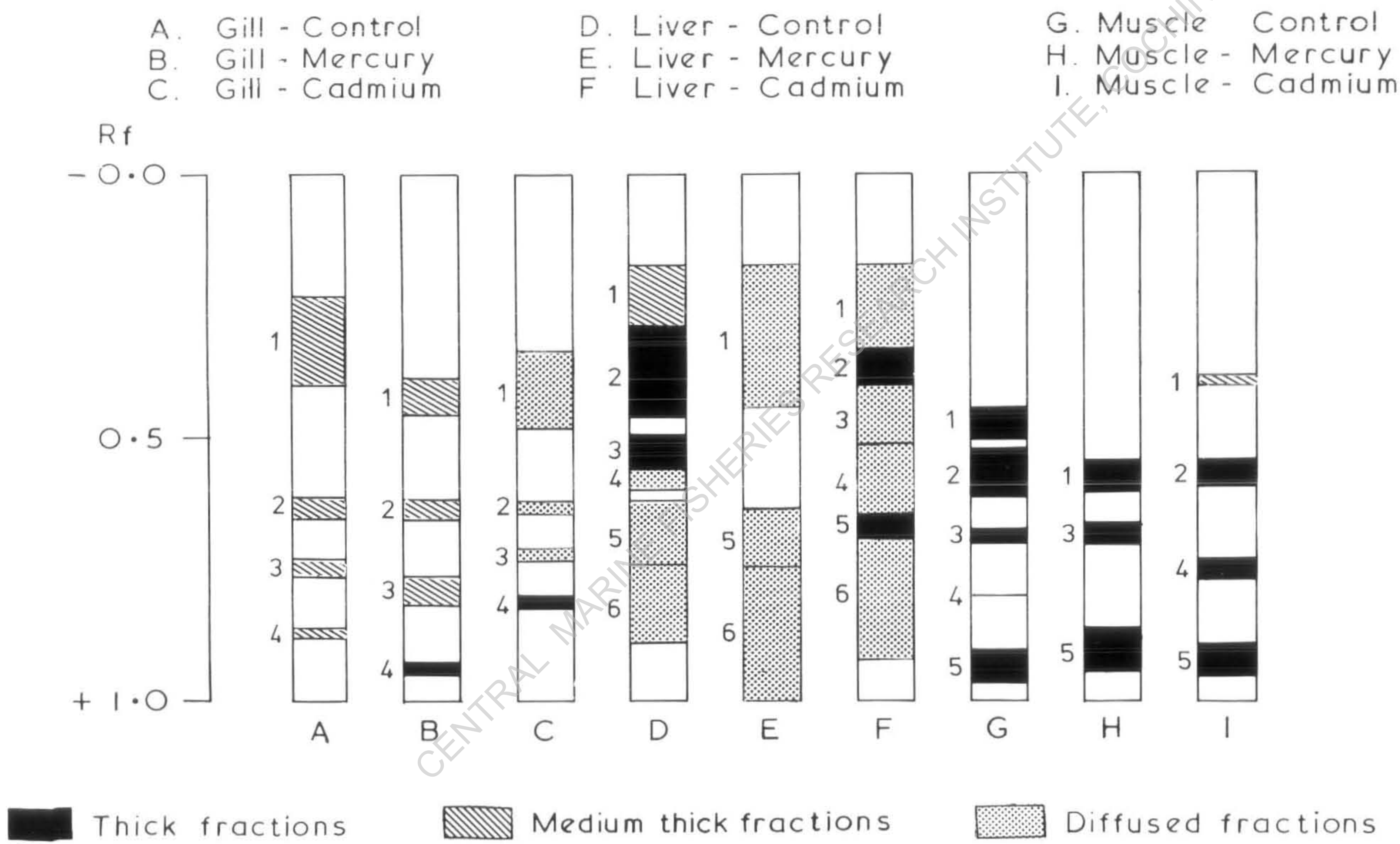
When mullets were exposed to mercury at 96 h Lc 50 level (360 ppb), the muscle bundles were completely disrupted with discontinuity of striations (Fig. 55 B). The lack of striations due to constrictions were reported already by Field (1960). The muscle bundles have no vacuolation and the muscle fibres showed ring fibres. The gap between two muscle bundles have widened to 21 µ when compared to the control set where the gap measures about 7 µ (Fig. 55 C).

3.5.9 Changes in muscle tissue when exposed to cadmium

When mullets were subjected to cadmium at 96 h Lc 50 level (2940 ppb), the muscle showed similar histopathological changes as observed in mercury treated fishes which include discontinuity in muscle bundles due to constriction (Fig. 55 D). The gap between each muscle bundle was seen to increase to about 17 µ when compared to the control fishes where it was about 7 µ. Besides the above changes, the disrupted muscle bundles were also observed to be infiltrated with mononuclear cells which suggest the atrophy of muscle bundles (Fig. 55 E). Further, the banding pattern was totally lost.

FIG. 56

DIAGRAMATIC REPRESENTATION OF PROTEIN FRACTIONS AFTER POLYACRYLAMIDE GEL ELECTROPHORESIS



3.6.0 Biochemical changes in protein content of gills, liver and muscle tissues of mullet, *Liza macrolepis* (Smith) after a treatment of 96 h Lc 50 levels of mercury and cadmium

3.6.1.0 Qualitative changes in protein content of gills, liver and muscle of mullet, *Liza macrolepis* (Smith) when exposed to 96 h Lc 50 levels of mercury (360 ppb) and cadmium (2940 ppb)

The breakdown of tissue proteins to be metabolised as energy source in fishes at times of stress has been well documented by several workers (Fountaine and Hatey, 1953; Idler and Clemens, 1959; Storer, 1967; Umminger, 1969; Castell *et al*., 1970; Mehrle *et al*., 1971; Kristoffersson *et al*., 1973; McLeay and Brown, 1974 & 1979; Gould and Karolus, 1974; Acke Larsson *et al*., 1976; Mukhopadhyay and Dehadrai, 1980; Sharma and Davis, 1980 and Gill and Pant, 1981). In the present study, qualitative changes in the soluble proteins of gill, liver and muscle tissues of mullet, *Liza macrolepis* (Smith) after subjecting the fishes to heavy metals (mercury 360 ppb and cadmium 2940 ppb) at 96 h Lc 50 levels were observed. Results are reported in Table 53 & Fig. 56)

3.6.1.1 Protein fractions in the gill tissue of untreated mullet *L. macrolepis*

In order to assess the normal pattern of protein

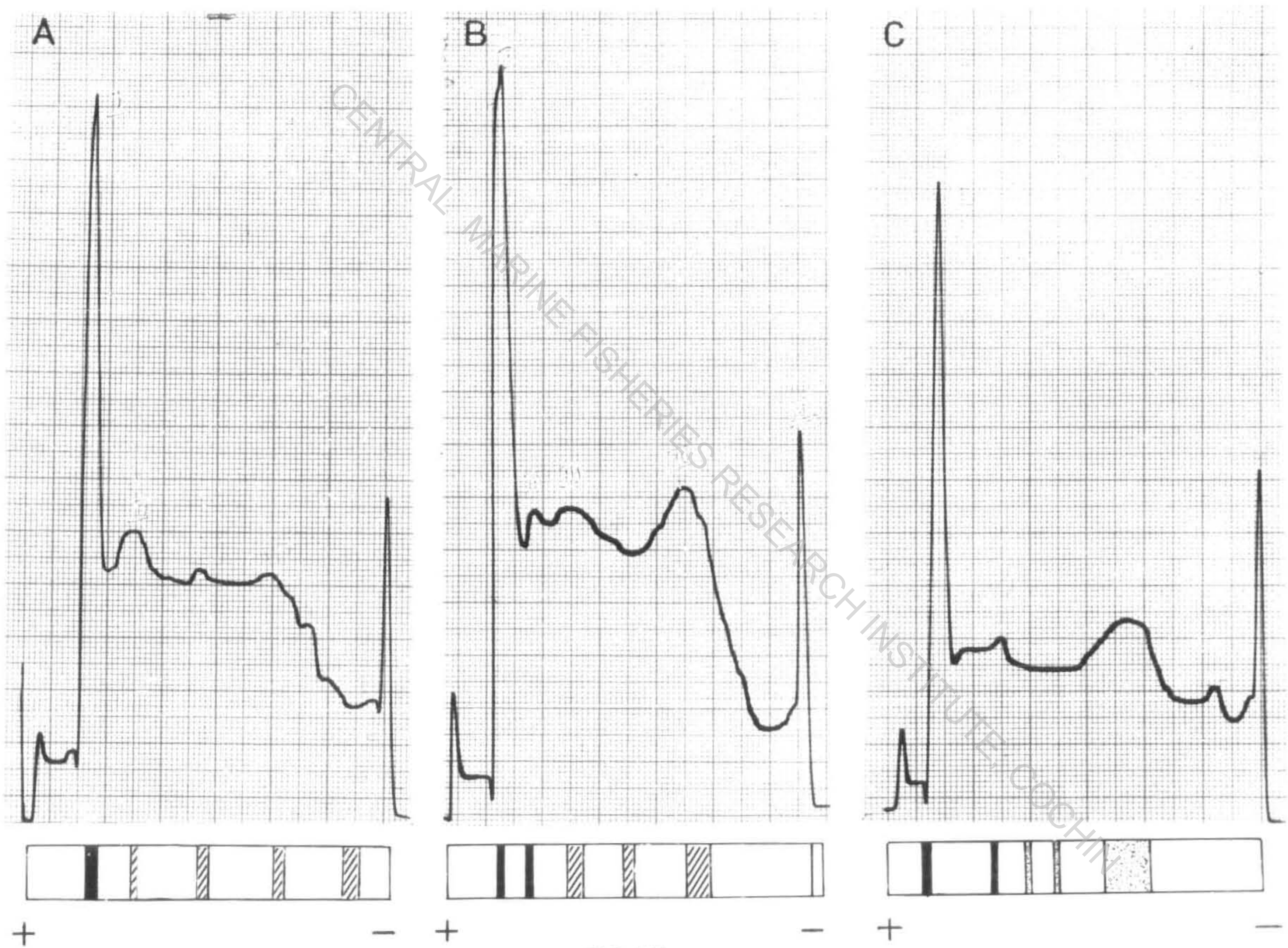


FIG. 57

Legend for figures

Fig.57

A - Electropherogram of protein of gill tissue of untreated mullet *L. macrolepis*.

B - Electropherogram of protein of gill tissue of mullet *L. macrolepis* when exposed to mercury.

C - Electropherogram of protein of gill tissue of mullet *L. macrolepis* when exposed to cadmium.

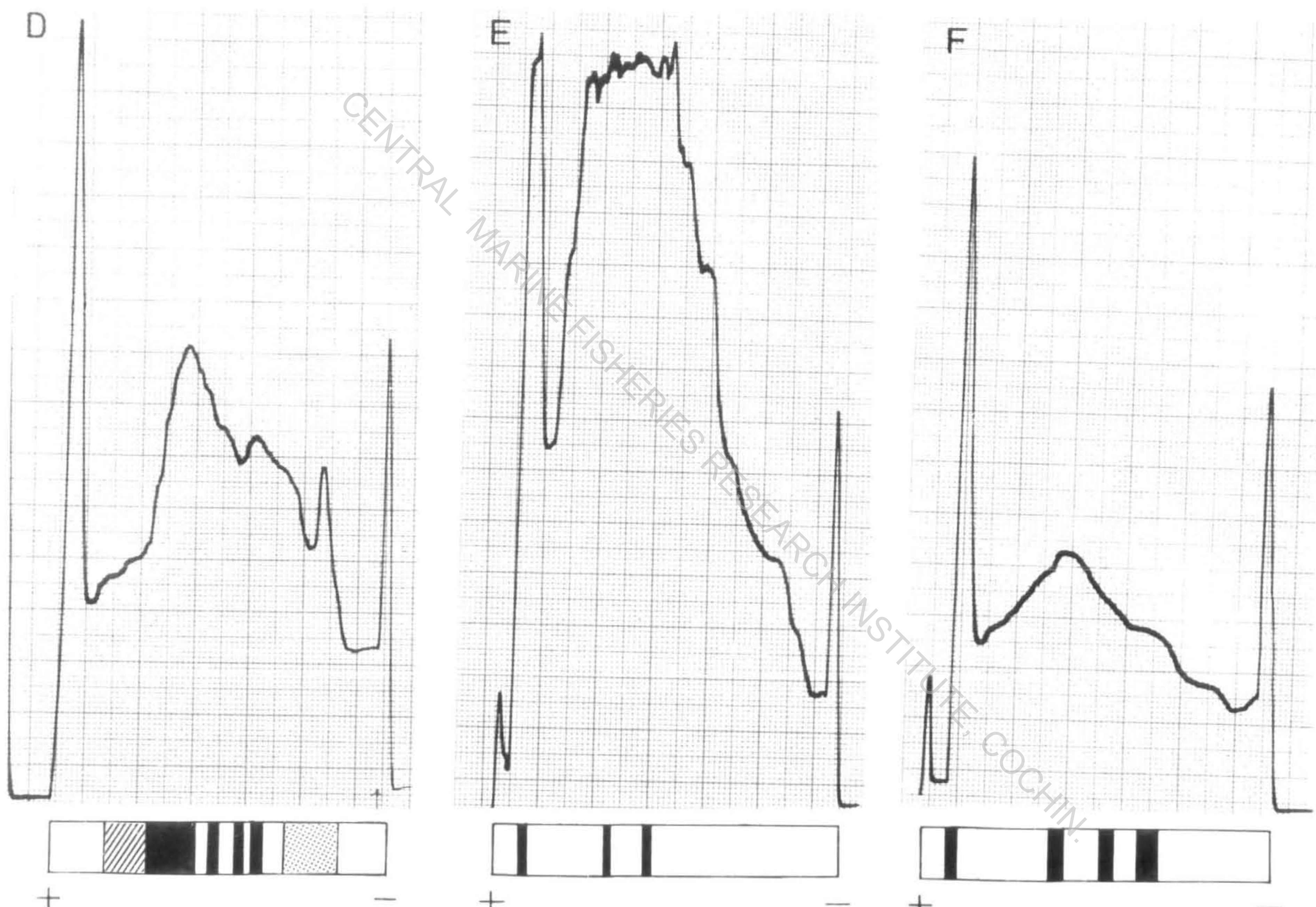


FIG. 58

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Fig.58

A - Electropherogram of protein of liver tissue of untreated mullet *L. macrolepis*.

B - Electropherogram of protein of liver tissue of mullet *L. macrolepis* when exposed to mercury.

C - Electropherogram of protein of liver tissue of mullet *L. macrolepis* when exposed to cadmium.

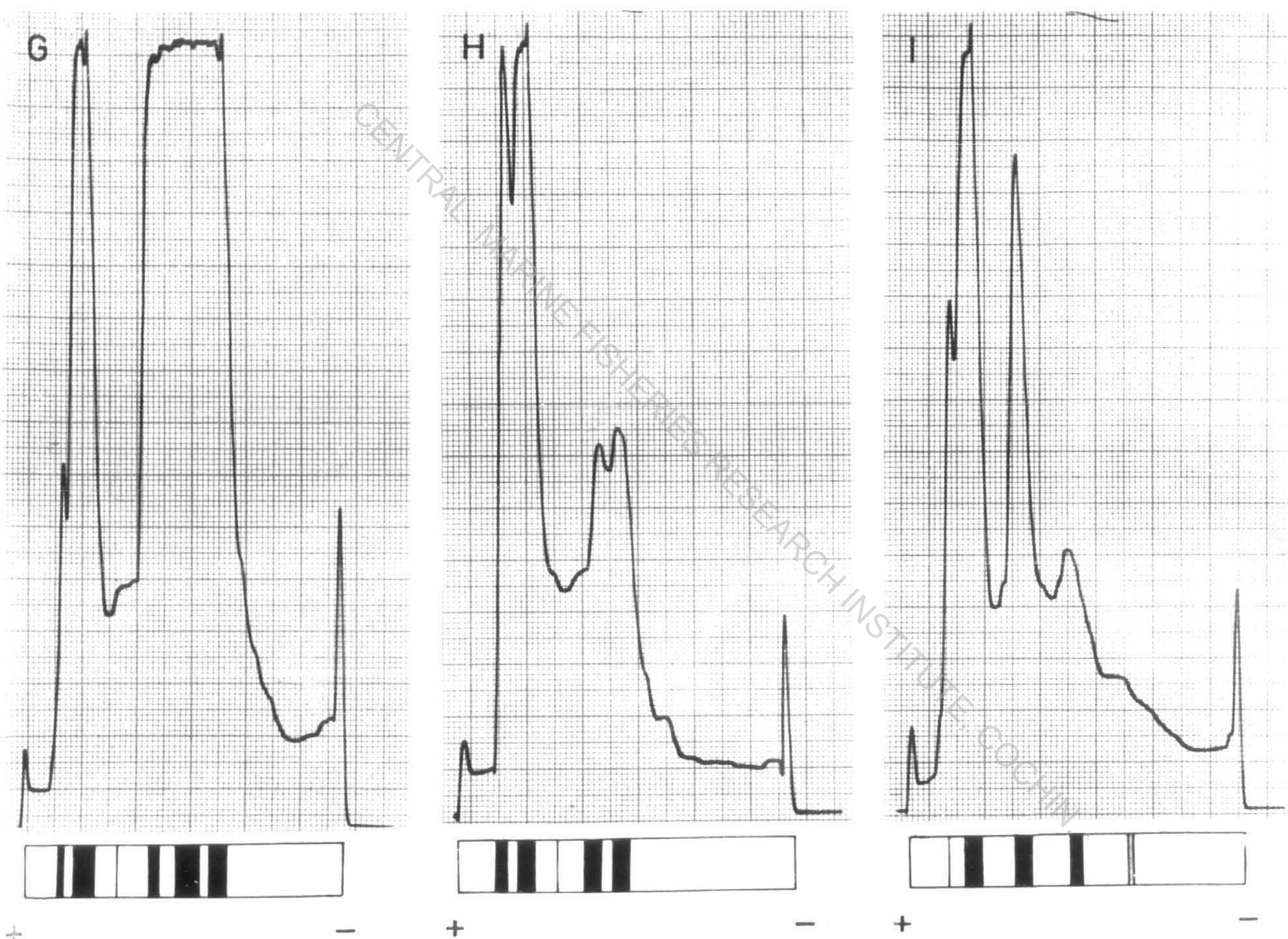

FIG. 59

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Fig.59

A - Electropherograms of protein of muscle tissue of untreated mullet *L. macrolepis*.

B - Electropherogram of protein of muscle tissue of mullet *L. macrolepis* when exposed to mercury.

C - Electropherogram of protein of muscle tissue of mullet *L. macrolepis* when exposed to cadmium.

fractions in the gill tissue of untreated mullets, a series of electrophoretic runs were made. It was found that there are four protein fractions in it with the following Rf values, 0.31, 0.63, 0.74 and 0.87. Of these fractions, the first band with an Rf value of 0.31 was considered as slow moving fraction and the other three bands with their Rf values between 0.63 to 0.87 were considered as fast moving.

The above classification is based on the work of Horn and Kerr (1969); Uglow (1969 a, 1969 b) and Fielder et al., (1971). It may be mentioned that there is no middle moving band. All the four fractions are denser in nature (Fig. 56).

Densitometric recordings of the electropherograms were made in order to study the changes, if any, in the protein fractions of the tissues of untreated and treated mullets with mercury and cadmium. (Figs. 57 ABC 58 DEF & 59 GHI).

3.6.1.2 Changes in the protein fractions of gill tissue when exposed to mercury

It may be seen from Table 53 that there was no change in the number of fractions in the gill proteins of mullet treated with mercury. However, the fractions obtained showed slow mobility. The Rf values for the four fractions were found to be 0.41, 0.63, 0.74 and 0.93 respectively. The Rf value of first band being 0.41, falls within a distance of 38 to 45 mm from the point of origin. On this basis it may be considered as a middle moving band. The Rf values of rest of the three bands were observed as 0.63, 0.74 and 0.93 respectively and that they may be considered as fast moving bands. The differences observed in the Rf values of different bands may be mainly due to the changes in the rate of mobility of the fractions. It may be reasonable to infer that exposure of mullets to heavy metals may bring about qualitative changes in proteins.

3.6.1.3 Changes in the protein fractions of gill tissue when exposed to cadmium

In the case of gills of mullet treated with cadmium the same number of protein fractions as observed in control fish was noted. However, the rate of mobility of the fractions consequent to exposure was radically changed when compared with the mobility of proteins of the untreated mullets. It may be seen that among the four protein fractions, one middle moving band with a Rf value of 0.45 and three fast moving bands with Rf values 0.63, 0.72 and 0.81 were observed. The fractions appearing in positions 1 to 3 were diffused. That there is a change in the rate of mobility of the bands consequent to the exposure of mullets to heavy metals may be indicative of corresponding changes in the configuration of proteins.

3.6.1.4 <u>Protein fractions in the liver tissue of untreated mullet *L. macrolepis*</u>

In the untreated mullets, a total number of six fractions were detected in the liver proteins, the Rf values being 0.23, 0.37, 0.53, 0.58, 0.68 and 0.81 respectively. Of these fractions, one slow moving (Rf value of 0.23), three middle moving (Rf values between 0.37 to 0.58) and two fast moving bands (Rf values of 0.68 and 0.81) were detected. It may be seen that low mobility fractions in the slow and middle moving positions are denser and the high mobility fractions in the fast moving positions appeared diffused.

3.6.1.5 <u>Changes in the protein fractions of liver tissues when exposed to mercury</u>

Treatment of mullets with mercury resulted in the exhibition of a faint diffuse zone in the electropherograms of liver proteins. It comprised of three fractions of which one was a slow moving (Rf value of 0.30) band and the other two were fast moving bands (Rf values of 0.68 and 0.87). A marked increasee in the intensity of staining of the fast moving protein bands were observed (Densitometric Fig. 59 E). The disappearance of protein bands 2 to 4 were observed which may be indicative of possible degradation and utilization of proteins (Djangmah, 1970 and Kristoffersson and Broberg, 1971).

3.6.1.6 Changes in the protein fractions of liver tissue when exposed to cadmium

In the case of liver proteins of the mullet treated with cadmium, no change in the number of protein bands was noticed. However, changes in the Rf values of protein fractions suggest a change in the rate of mobility. Such a change is not significant enough to alter the total number of bands in each of the three subdivision of band mobility. As a result there was one slow moving, three middle moving and two fast moving bands. All the bands appeared distinct.

3.6.1.7 Protein fractions in the muscle tissue of untreated mullet *L. macrolepis*

In the muscle protein of healthy untreated mullets, there were present five fractions, their Rf values were found to be 0.47, 0.56, 0.68, 0.80 and 0.90 respectively. Of these, there are two middle moving bands having the Rf values of 0.47 and 0.56 and three fast moving bands with Rf values between 0.68 to 0.90. The middle and fast moving protein bands are denser in appearance. There was no slow moving fraction.

3.6.1.8 Changes in the protein fractions of muscle tissue when exposed to mercury

It may be seen from Table 53 that there were only three protein fractions in the muscle of mullet treated with mercury and their Rf values were found to be 0.57, 0.68 and 0.90 respectively. Of the three, one band was categorized as a middle moving fraction with an Rf value of 0.59 and the other two were designated as fast moving bands with Rf values of 0.68 and 0.90. The disappearance of second and fourth protein fractions were observed in the fast moving positions of the fractions indicating the cellular degradation of the proteins in the muscle (Mckim, et al., 1970).

3.6.1.9 Changes in the protein fractions of muscle tissue when exposed to cadmium

In the case of protein fractions of the muscle of mullets treated with cadmium four bands were observed, the Rf values being 0.39, 0.56, 0.75 and 0.92. Of these, the first two bands with Rf values of 0.39 and 0.92 were middle moving bands. The third sharply differenciated fast moving band, observed in the control, disappeared in the experimental runs. The fourth and fifth bands with Rf values of 0.75 and 0.92 were found to be fast moving. All the fast moving fractions appeared denser.

3.6.2.0 Quantitative changes in protein content of gills, liver and muscle of mullet, *Liza macrolepis* (Smith) exposed to 96 h Lc 50 levels of mercury (360 ppb) and cadmium (2940 ppb).

Depletion of tissue proteins in fish exposed to toxicants

TABLE 54 TOTAL PROTEIN CONTENT IN THE GILL TISSUE OF <u>LIZA MACROLEPIS</u> (SMITH) EXPOSED TO HEAVY METALS (MERCURY & CADMIUM) AT 96 h Lc 50 LEVEL (IN PERCENTAGES mg/5 mg DRY WEIGHT)

S.NO.	CONTROL	MERCURY	CADMIUM
1	38.0	26.5	29.0
2	39.5	29.0	34.0
3	40.0	26.0	36.5
4	40.5	32.5	27.5
5	40.0	27.0	35.5
MEAN	39.6	28.2	32.5
S.D. ±	0.96	2.65	4.01
S.E.	0.49	1.37	2.08

TOTAL PROTEIN CONTENT IN THE LIVER TISSUE OF <u>LIZA MACROLEPIS</u> (SMITH) EXPOSED TO HEAVY METALS (MERCURY & CADMIUM) AT 96 h Lc 50 LEVEL (IN PERCENTAGES mg/5 mg DRY WEIGHT)

S.NO.	CONTROL	MERCURY	CADMIUM
1	47.5	37.0	37.0
2	46.0	38.5	47.5
3	50.0	38.0	47.5
4	46.0	42.0	42.5
5	48.5	36.0	42.5
MEAN	47.6	38.2	43.4
S.D. ±	1.71	2.28	4.36
S.E.	0.88	1.18	2.26

TOTAL PROTEIN CONTENT IN THE MUSCLE TISSUE OF <u>LIZA MACROLEPIS</u> (SMITH) EXPOSED TO HEAVY METALS (MERCURY & CADMIUM) AT 96 h Lc 50 LEVEL (IN PERCENTAGES mg/5 mg DRY WEIGHT)

S.NO.	CONTROL	MERCURY	CADMIUM
1	41.0	39.0	35.0
2	42.5	40.0	39.0
3	44.0	34.5	40.0
4	47.5	38.0	41.0
5	46.0	36.0	42.0
MEAN	44.2	37.4	39.4
S.D. ±	2.61	2.07	2.70
S.E.	1.32	1.07	1.40

have been reported by several workers (Castell _et al._, 1970; Gould and Karolus, 1974; Sharma and Davis, 1980; Mukhopadhyay and Dehadrai, 1980). In the present study, in order to assess the influence of heavy metals such as mercury and cadmium on the total tissue protein levels of gill, liver and muscle of mullet, _Liza macrolepis_ (Smith), tests were conducted at 96 h Lc 50 levels and the tissue proteins were estimated using the Lowry's method (1951). The results are given in Table 54.

The total protein content of the gills of control mullet ranged from 38.0 to 40.0% the mean percentage being 39.6. When the mullets were exposed to mercury, the protein content was reduced and it ranged from 26.0 to 32.5 the mean percentage being 28.2. In the case of mullets subjected to cadmium treatment, the estimated protein content ranged from 29.0 to 36.5% the mean percentage being 32.5.

In the control mullets the total protein content of liver ranged from 46.0 to 50.0%, the mean percentage being 47.6. When the mullets were subjected to mercury, the protein content decreased and it ranged from 36.0 to 42.0%, the average being 38.2%. In the case of mullets exposed to cadmium, the protein content ranged from 37.0 to 47.5% the mean value being 43.4%.

The total protein content of the muscle of control mullets ranged from 41.0 to 47.5%, the mean percentage being 44.2. When the mullets were subjected to mercury, the

Table 55 Statistical inference

Name of the toxicant at Lc 50 level	Gill Calculated Student 't'	Liver Calculated Student 't'	Muscle Calculated Student 't'	Inference *
Mercury	6.24	5.87	3.81	Significant difference
Cadmium	4.08	2.98	7.95	Significant difference

* Table 't' value at 5% level 2.98

percentage of protein content was reduced and it ranged from 34.5 to 40.0, the average being 37.9%. In the case of mullets exposed to cadmium, the protein content ranged from 35.0 to 42.0% and the mean percentage was 39.4

In conclusion, it may be stated that there is a significant change in the total protein content of the gill, liver and muscle tissues of mullets exposed to mercury and cadmium at 96 h Lc 50 levels. The effect of mercury appears to be pronounced than cadmium.

In order to find out the statistical significance of the variation, the percentages of total protein content values of gill, liver and muscle tissues of mullets before and after treatment were compared by using the appropriate Student's 't' test and the results are presented in Table 55. It may be seen from Table 55 that the calculated 't' value of all the organs such as gill, liver and muscle are greater than the Table 't' value at 5% level of significance and it may be inferred that variation in protein contents before and after treatment are statistically significant and hence exposure of mullets to heavy metals bring about significant changes in the level of protein.

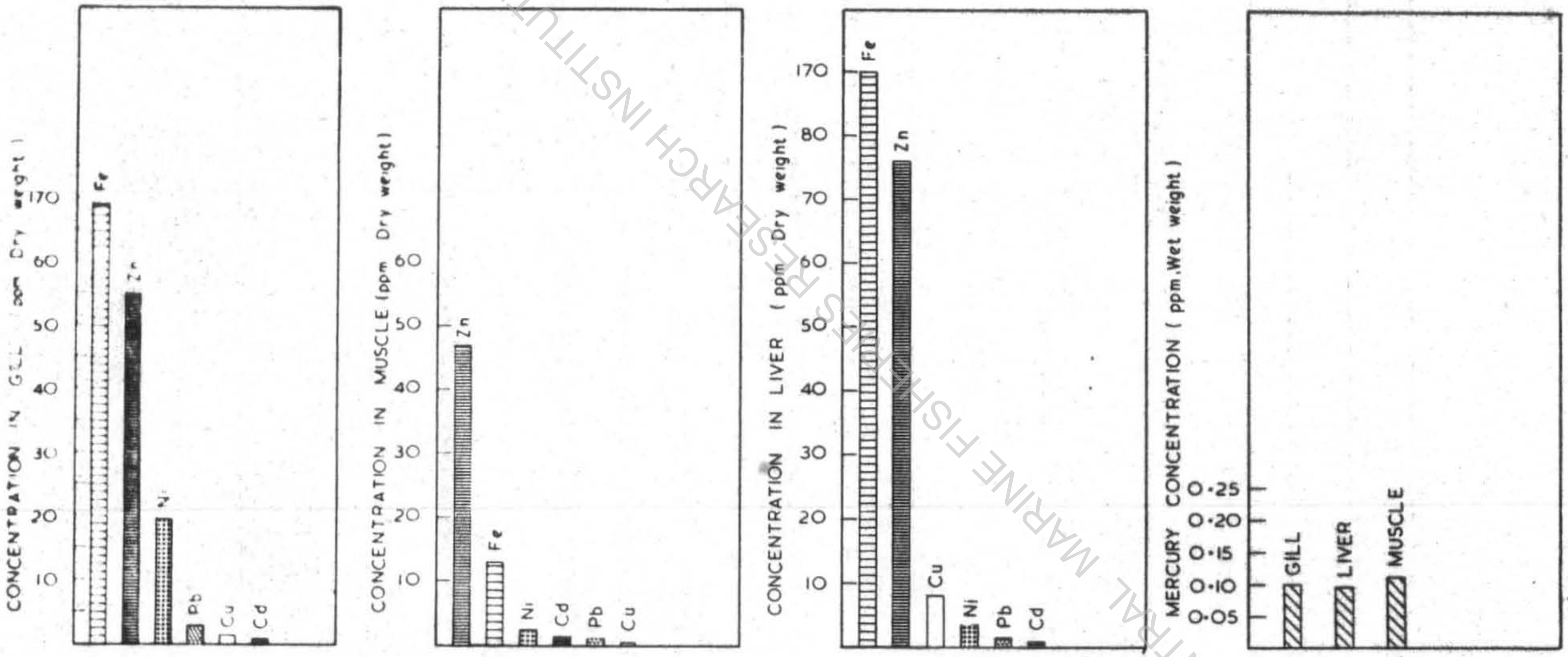
TABLE 56 HEAVY METALS CONCENTRATIONS IN GILL, LIVER AND MUSCLE TISSUES OF MULLET, *LIZA MACROLEPIS* (SMITH) FROM ADYAR ESTUARY, MADRAS.

HEAVY METALS	GILL (ppm/dry wt)	LIVER (ppm/dry wt)	MUSCLE (ppm/dry wt)
CADMIUM (Cd)	0.74	0.78	1.55
COPPER (Cu)	1.63	8.19	0.60
ZINC (Zn)	55.21	76.68	47.15
NICKEL (Ni)	19.89	3.61	2.45
LEAD (Pb)	2.83	1.51	1.25
IRON (Fe)	163.72	170.18	12.75
PERCENTAGE OF WATER CONTENT	80.31	79.78	78.94

HEAVY METALS	GILL (ppm/wet wt)	LIVER (ppm/wet wt)	MUSCLE (ppm/wet wt)
MERCURY (Hg)	0.10	0.09	0.12

GILL:	Fe	>	Zn	>	Ni	>	Pb	>	Cu	>	Cd	>	Hg
LIVER:	Fe	>	Zn	>	Cu	>	Ni	>	Pb	>	Cd	>	Hg
MUSCLE:	Zn	>	Fe	>	Ni	>	Cd	>	Pb	>	Cu	>	Hg

FIG 60 Heavy metals concentrations in gill muscle and liver tissues of mullet *Liza macrolepis* (Smith) collected from the Adyar estuary, Madras



3.7.0 Heavy metals concentrations in gills, liver and muscle tissues of mullet *Liza macrolepis* (Smith) from Adyar Estuary, Madras

The distribution and concentration of the following trace elements namely mercury, cadmium, copper, zinc, nickel, lead and iron in the tissues of gills, liver and muscle of mullet, *Liza macrolepis* (Smith) inhabiting the Adyar estuary are summarised in Table 56 & Fig. 60.

3.7.1 Concentrations of heavy metals in gills

It may be seen from the Table that there are variations among the concentration of different elements when ranked on the basis of their concentration, it is found that iron occurred in highest concentration (163.72 ppm) and mercury occurred in lowest concentration (0.10 ppm). The incidence of heavy metals in the mullet may be ranked as follows on the basis of their concentration: iron (163.72 ppm), zinc (55.21 ppm), nickel (19.89 ppm), lead (2.83 ppm), copper (1.63 ppm), cadmium (0.74 ppm) and mercury (0.10 ppm).

Fe > Zn > Ni > Pb > Cu > Cd > Hg

3.7.2 Concentration of heavy metals in liver

The seven elements assessed in the present investigation were identified in the liver tissue and their concentrations vary from that of the gill tissue. Iron was found to occur in highest concentration (170.18 ppm) and mercury was found to occur in the low concentrations (0.09 ppm). They may be ranked as follows:

Iron (170.18 ppm), zinc (76.68 ppm), copper (8.19 ppm), nickel (3.61 ppm), lead (1.51 ppm), cadmium (0.78 ppm) and mercury (0.09 ppm)

Fe > Zn > Cu > Ni > Pb > Cd > Hg

In comparison with the gill tissue, it may be seen that in both the gill and liver tissue, iron and zinc occurred in appreciable amount and wide variation was seen in the case of copper. Further, cadmium and mercury occur in low quantities in both the tissues.

3.7.3 <u>Concentrations of heavy metals in muscle</u>

It may be noted from the Table that all the seven elements are also present in the muscle tissue but with varying concentrations. They may be ranked as follows:

Zinc occurred in highest concentration (47.15 ppm) and mercury occurred in lowest concentration (0.12 ppm). The following order may be noticed.

Zinc (47.15 ppm), iron (12.75 ppm), nickel (2.45 ppm), cadmium (1.55 ppm), lead (1.25 ppm), copper (0.60 ppm) and mercury (0.12 ppm).

Zn > Fe > Ni > Cd > Pb > Cu > Hg

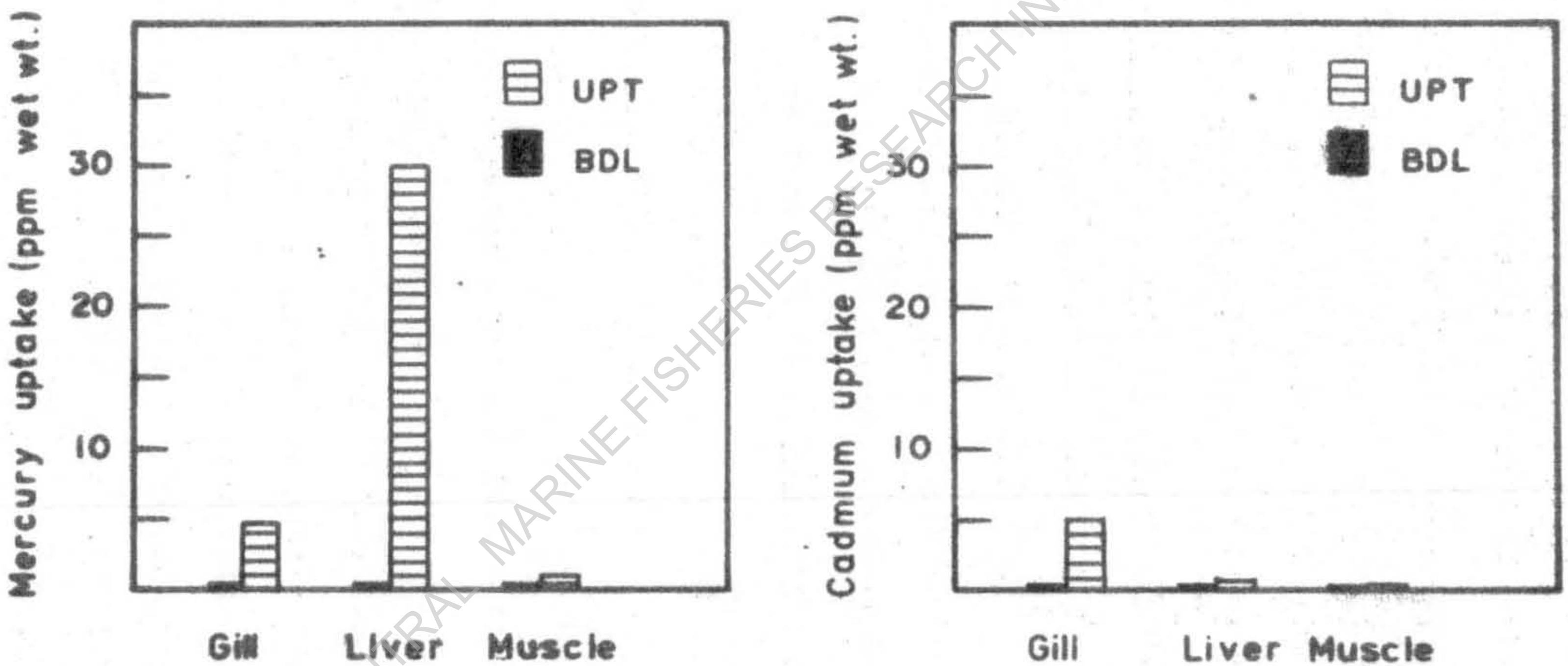
TABLE 57 BIOACCUMULATION OF HEAVY METALS MERCURY AND CADMIUM BY MULLET, LIZA MACROLEPIS (SMITH) EXPOSED AT 96 h Lc 50 LEVEL

NAME OF THE HEAVY METALS	MERCURY Lc 50 LEVEL (ppm)	GILL (ppm/wet wt)	LIVER (ppm/wet wt)	MUSCLE (ppm/wet wt)
MERCURY UPTAKE (WET WT)	0.36	4.70	30.10	0.80
MERCURY BACK-ROUND LEVEL (BDL)	-	0.10	0.09	0.12
CONCENTRATION FACTOR (CF)	0.36	13.05	83.61	2.22
Cd UPTAKE (WET WT)	2.94	5.23	0.72	0.56
Cd BACKROUND LEVEL (WET WT)	-	0.02	0.04	0.08

NAME OF THE HEAVY METALS	CADMIUM Lc 50 LEVEL (ppm)	GILL (ppm/dry wt)	LIVER (ppm/dry wt)	MUSCLE (ppm/dry wt)
CADMIUM UPTAKE/ ACCUMULATION	2.94	31.94	3.18	2.38
PERCENTAGE OF WATER CONTENT	-	83.63%	77.03%	76.24%
CADMIUM BACKROUND LEVEL (BDL)	-	0.74	0.78	1.55
PERCENTAGE OF WATER CONTENT	-	80.31%	79.78%	78.94%

CONCENTRATION FACTOR	GILL (ppm/dry wt)	LIVER (ppm/dry wt)	MUSCLE (ppm/dry wt)
(CF)	1.78	0.24	0.19

FIG.61 BIOACCUMULATION OF MERCURY & CADMIUM AT 96 h: Lc 50 LEVELS IN GILL LIVER AND MUSCLE TISSUES OF *L. macrolepis*



It would appear from the foregoing report that there is variation in the degree of concentration of the elements leading to variation in the sequential listing of the elements when arranged on the basis of their concentration. Zinc and iron appear to be most dominant bioaccumulant and the concentratoon of mercury is appreciably low. Among the three tissues, bioaccumulation is less in the muscle tissue.

3.8.0 Bioaccumulation of mercury and cadmium in gills, liver and muscle tissues of mullet, *Liza macrolepis* when exposed to 96 h Lc 50 levels of mercury and cadmium

In order to evaluate the bioaccumulation of heavy metals (mercury and cadmium), by gills, liver and muscle of mullet, *Liza macrolepis* (Smith) at 96 h Lc 50 levels, tests were conducted and the results are given in Table 57 & Fig. 61.

3.8.1 Bioaccumulation of mercury in the gill tissue of mullet

It may be seen from Table 56 that in the gills of untreated mullets, the concentration of mercury was found to be in the order of 0.10 ppm. When mullets were exposed to mercury at Lc 50 level of 0.36 ppm, the uptake level of mercury by the tissue was raised to 4.70 ppm suggesting thereby an inflow of mercury from the ambient environment. The rate of uptake was found to be increased by about thirteen times (CF=13.05).

Concentration factor (CF) was derived as follows:

$$CF = \frac{\text{Concentration of Hg in ppm/gm of wet weight of tissue}}{\text{Concentration of Hg in ppm/litre of sea water}}$$

3.8.2 Bioaccumulation of cadmium in the gill tissue of mullet

The pretreatment level of cadmium in the gills was found to be 0.02 ppm. After exposure of the fish to a medium containing cadmium at Lc 50 level of 2.94 ppm, the uptake level of cadmium by the tissue was raised to 5.23 ppm, thus showing 100% increase in the level of uptake by the tissue (CF=1.78).

3.8.3 Bioaccumulation of mercury in the liver tissue of mullet

In the case of freshly caught mullets resident level of mercury in the liver tissue was recorded as 0.09 ppm. The posttreatment level, at Lc 50 level 0.36 ppm, of mercury in the liver tissue was estimated as 30.10 ppm, which is about eightythree times more than the base line concentration. The rate of bioaccumulation of mercury appeared to be higher in liver tissue than in the gill tissue (CF=83.61).

3.8.4 Bioaccumulation of cadmium in the liver tissue of mullet

In the untreated mullets,, the concentration of cadmium in the liver was found to be 0.24 ppm which was increased to 0.72 ppm after treatment with cadmium at Lc 50 level of 2.94 ppm (CF=2.24). The above results indicate that between the two elements, mercury seems to infiltrate faster and the degree of accumulation is also greater.

3.8.5 Bioaccumulation of mercury in the muscle tissue of mullet

In the muscle tissue of untreated mullets, a concentration of 0.12 ppm of mercury was found. It is interesting to note that the posttreatment concentration of mercury at Lc 50 level 0.36 ppm showed a two fold increase in the uptake rate, the value being 0.80 ppm (CF=2.22).

3.8.6 Bioaccumulation of cadmium on the muscle tissue of mullet

It may be noted from the Table that a concentration of 0.08 ppm of cadmium was observed in the muscle of untreated mullets, whereas a meagre amount of cadmium from the experimental medium was added to the tissue, the concentration being 0.56 ppm (CF=0.19).

Laboratory experiments on bioaccumulation studies of heavy metals (mercury and cadmium) on mullet, *L. macrolepis* indicate that the rate of uptake of mercury and cadmium by the muscle tissue of mullet at 96 h Lc 50 level was lesser when compared to gill and liver tissues. These studies substantiated the findings of lesser bioaccumulation levels of mercury and cadmium on the muscle tissues of mullets collected from the natural samples of Adyar estuary, Madras.

3.9.0 Effects of mercury and cadmium at 96 h Lc 50 levels on the biomass of gills, liver and muscle of mullet *Liza macrolepis* (Smith)

Variations in the content of water in gills, liver and

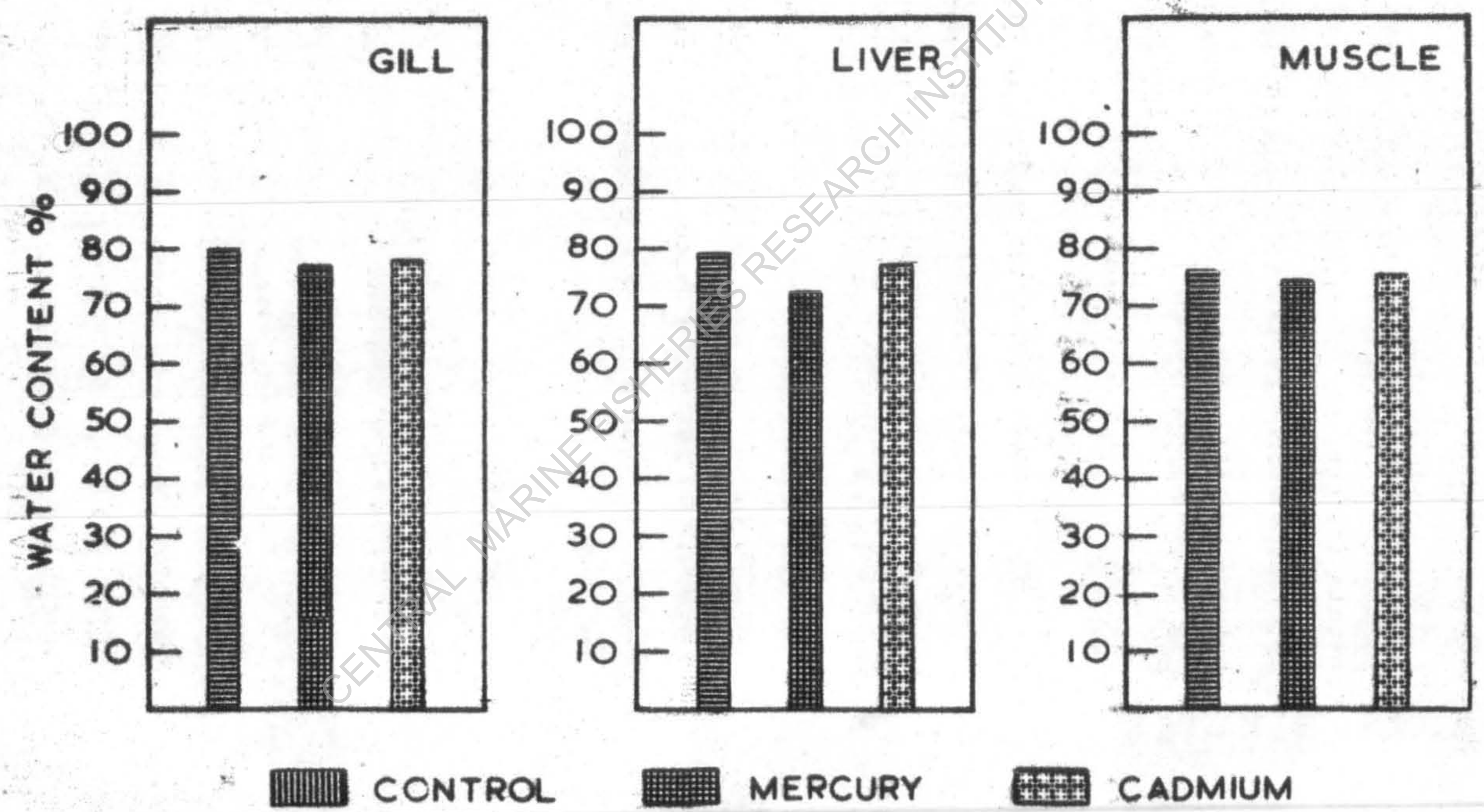
Table 58 A Water content of the tissues (in percentages) of mullet <u>Liza macrolepis</u> (Smith) at 96 h Lc 50 levels of mercury and cadmium

	Gill (%)	Liver (%)	Muscle
Control	80.30	79.19	76.92
Mercury	77.18	72.09	74.61
Cadmium	78.77	77.46	75.91

Table 58 B Weight (wet weight) of the tissues (in percentages of mullet, <u>Liza macrolepis</u> (Smith) in relation to the weight of the body at 96h Lc 50 levels of mercu and cadmium

	Gill (%)	Liver (%)	Muscle
Control	4.45	2.25	22.04
Mercury	3.79	1.47	19.92
Cadmium	4.12	1.89	20.16

FIG. 62 CHANGES IN THE WATER CONTENT BEFORE AND AFTER TREATMENT OF MERCURY AND CADMIUM AT 96 h Lc 50 LEVELS



muscle tissues of mullets before and after exposure to heavy metals (mercury and cadmium) at 96 h Lc 50 levels were assessed in order to find out the influence of heavy metals on water holding capacity of the different tissues under stressed conditions. The results are given in Table 58 A and Fig. 62.

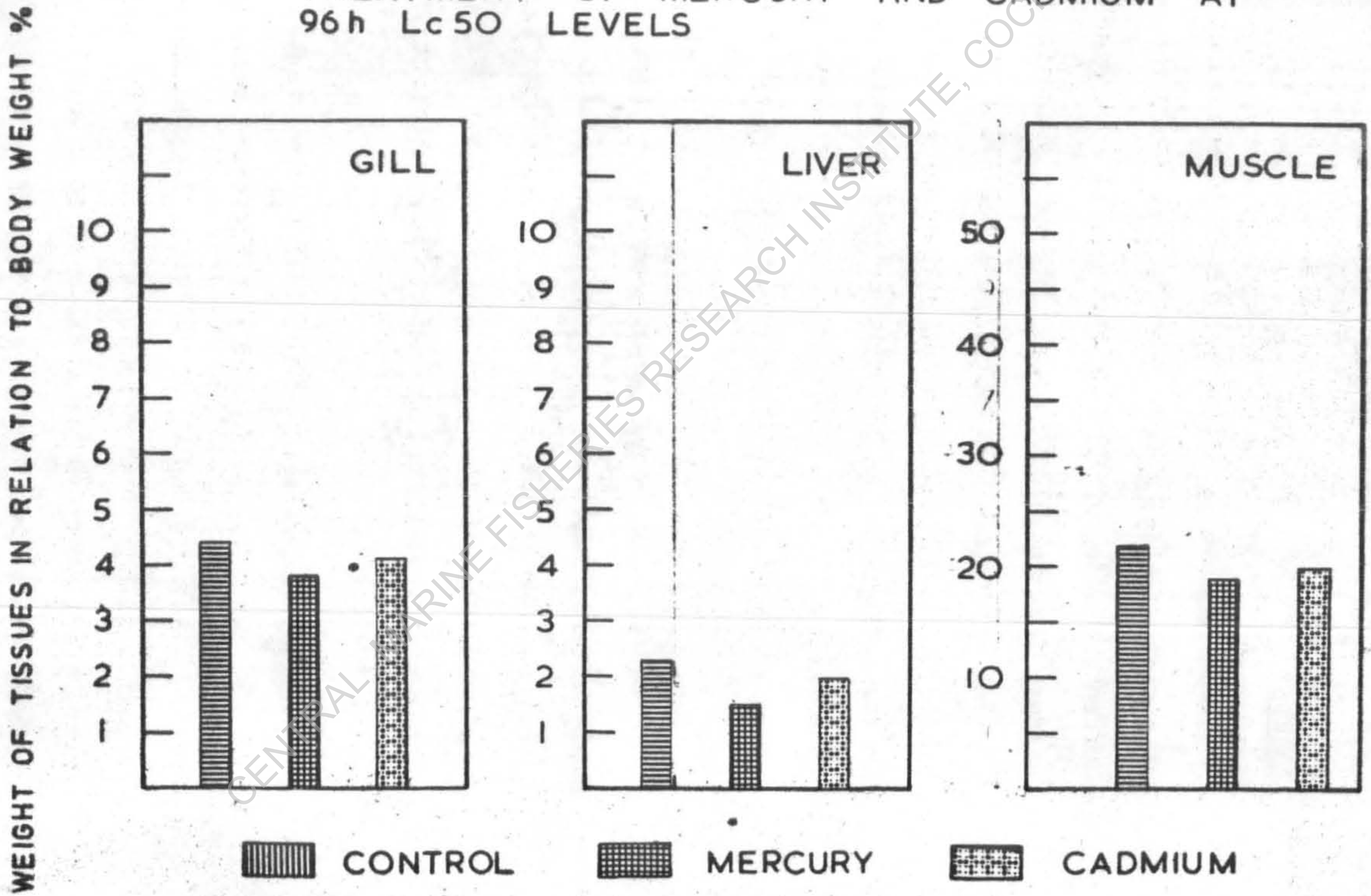
Gills:

The percentage of water content in the gills of untreated mullets ranged from 78.1 to 82.0%, the mean value being 80.3%. After a period of 96 h exposure to mercury at 360 ppb there was a reduction in the water content. The percentage ranged from 75.8 to 79.7%, the mean percentage being 77.1%. In the case of mullets exposed to cadmium at 2940 ppb, the estimated percentage of water content ranged from 77.7 to 80.8%, the mean percentage being 78.7%.

Liver:

The pretreatment water content of liver tissue of the mullets ranged from 77.7 to 81.8%, the mean percentage being 79.1%. When the mullets were exposed to mercury, the percentage of water content was decreased and it ranged from 70.6 to 74.6, the mean percentage being 72.0%. After a period of 96 h exposure of fish to water containing 2940 ppb of cadmium, a decrease in the water holding capacity as evidenced by low water content was noticed. The percentage of water ranged from 75.9 to 79.4, the mean percentage being 77.4%.

FIG. 63 CHANGES IN THE WEIGHT BEFORE AND AFTER TREATMENT OF MERCURY AND CADMIUM AT 96h Lc50 LEVELS



Muscle:

The percentage of water content in the muscle tissue of control mullets ranged from 75.3 to 78.5, the mean percentage being 76.9% When the mullets were exposed to mercury for a period of 96 h, the mean percentage of water content was reduced to 74.6%,the range being 72.8 to 76.6%. Similarly, a reduction in the percentage of water content in the muscle tissue was recorded when mullets were exposed to cadmium. The mean percentage of water content was in the order of 75.9%, while the individual variation ranged from 74.6 to 77.3%.

Differences in the water content and changes in the protein fractions leading to the disappearance of certain bands suggest that the weight of an organ when expressed as the percentage of the total body weight may serve as an index of stress conditions due to the introduction of heavy metal toxicants.

In the present study in order to compare the differences in percentage weight (wet wt) of different tissues such as gills, liver and muscle of mullet L. macrolepis in relation to total weight of the fishes before and after exposure to heavy metals mercury and cadmium at 96 h Lc 50 levels tests were conducted and the results are presented in Table 58 B & Fig. 63.

Gills:

It may be seen that (Table 58 B & Fig. 65) the percentage weight of the gill tissue of the untreated mullets, in relation to the total weight of the fishes, ranged from 3.6 to 4.7%, the mean percentage being 4.2%. There was a marked reduction in the ratio in fishes exposed to a mercury concentration of 360 ppb. The ratio ranged from 2.4 to 3.4%, the mean percentage value being 2.9%. In the case of mullets exposed to cadmium (2940 ppb) the reduction in percentage of weight ranged from 2.9 to 3.9%, the mean percentage being 3.4%.

Liver:

Similar relationship was noticed in the liver tissue also. In control fishes, the ratio ranged from 1.8 to 2.6%, the average percentage being 2.2%. When mullets were exposed to mercury at 96 h Lc 50 level (360 ppb), the mean percentage weight of the liver decreased to 1.4%, the range being 1.1 to 1.6%. After a period of 96 h treatment with cadmium at 96 h Lc 50 level (2940 ppb) the percentage weight of the liver also showed a reduction. The individual variation ranged from 1.5 to 2.0%, the mean percentage being 1.8%.

Muscle:

The pretreatment percentage weight of the muscle tissue of the mullets ranged from 19.8 to 25.2%, the average percentage being 23.3%. When the mullets were exposed to mercury at 96 h Lc 50 level (360 ppb), a reduction in the percentage weight was noticed. It ranged from 16.3 to 20.2%, the mean percentage being 18.0%. After a period of 96 h treatment with cadmium at Lc 50 level (2940 ppb), the mean percentage weight of the muscle tissue was reduced to 20.0%, the range being 18.9 to 22.1%.

The foregoing results suggest that mercury and cadmium at 96 h Lc 50 concentration profoundly affect the water holding capacity of gill, liver and muscle tissues of mullets.

4.0.0 DISCUSSION

The results of the present study have brought to light the existence of potentially good estuarine grounds for fish and prawn seed exploitation along the Madras Coast. Based on the relative abundance of fry and fingerlings of mullets, the following four estuaries namely Adyar, Ennore, Palar and Pulicat have been considered as areas of rich mullet assemblage. Chacko and Ganapathi(1949), Chacko (1951, 1952 & 1956), Anantharaman (1951), Chacko et al., (1953, 1954), Chacko and Rajagopal (1962), Evangeline (1968), Evangeline et al., (1969), Evangeline and Subbiah (1969), Prabakara Rao (1970) and Krishnan and Sampath (1976) have reported a maximum occurrence of about 35 to 40% of mullets in these estuaries during the years 1948, 1951-52, 1952-54, 1954-55, 1963-65, 1965-67, 1966-67 and 1971-72. When compared to their reports, data obtained (Tables 1, 2, 4 & 8) in the present study appear significant in that an increase of 50% i.e. about 95% of the seed abundance during October to December and 84% during April to June has been recorded over the earlier records. Evangeline and Subbiah (1969) and Evangeline et al., (1969), while commenting about the then existing percentage occurrence of mullet seed, drew attention to the role of the formation of sand bar at the mouth of the river. They emphasized that the abundance of fish seed within the estuary is governed by the length of time for which the river mouth was in continuity with the open sea coast. It is known that due to the long shore drift, the accumulation of sand is more intense on the coastal Madras (Azariah and Hilda, 1981). Such a phenomena blocks the river mouth preventing the entry of the fish seed. During the course of the present study, it has been observed that due to the constant maintenance work carried out by Tamil Nadu Public Works Department (Irrigation), the mouth of the following rivers: Pulicat, Ennore and Palar have been kept open throughout the year, while other estuaries like Kovalam, Edayar, Adyar and Cooum were found naturally in an open condition for a period of about 7 to 8 months during the North East monsoon flood season. The river mouth of Sadras estuary was in an open condition only for a short duration of 3 months. It is suggested that the augmentation of fish seed resource, as has been reported in the present study, may primarily be due to the open condition of the river mouth facilitating the entry of seed during most months of the year. The aforementioned observations conclusively provide supportive evidence that the opening of the river mouth is a critical factor in achieving abundant crop of mullets besides recuperation of the river during high tide period. By way of recommendation it is suggested that in future, maximum effort must be made to maintain an year-round continuity of all the estuaries with the sea in order to maintain a sustained augmentation of fish seed resource.

Another contributing factor that may influence the abundance of mullet seed is the nature of reproductive cycle of mullets. It is known that mullets, Liza macrolepis (Smith) breed throughout the year with two peak spawning periods (Rengaswamy, 1980). The two major spawning seasons occur during the months of October to December and April to June. Results of the present study confirms the earlier report on the occurrence of the two spawning seasons in that mullet seedlings were collected in abundance during the months of October to December and from April to June with relatively less abundant catch in the rest of the months. It is known that fry and fingerlings of mullets migrate into the estuarine regions soon after spawning (Panikkar and Ayer, 1939; Jacob and Krishnamurthy, 1948 and Rengaswamy, 1980). It is significant to note that, except in Sadras estuary where the bar month was open only for a short period of 3 months, in all other estuaries the peak abundance of mullet fry coincided with the peak spawning seasons of mullets suggesting thereby that the regulatory function of the river mouth coupled with the peak spawning season is a prime factor in the recruitment and seed abundance of mullets. At Sadras estuary, no seasonal abundance was observed in correlation with period of peak spawning.

The third feature of interest is the variation in the pattern of size group dominance. Evangeline et al., (1969) Krishnan and Sampath (1976) reported a 20% abundance of fingerlings measuring 100 mm in length in the Pulicat lake. In contrast to this report, it has been observed in the present study that fingerlings measuring lesser in size (55 mm) occurred throughout the year with a high percentage abundance (70%). The invasion of lesser size groups suggests good prospects for high fish crop yield after a few months of growth of fry in the estuarine waters. It is likely that the present record of abundance of lower size groups when compared to earlier reports may be taken as a positive indication for commercial exploitation.

Similar augmentation in prawn seed catch can be documented by comparing the present study with other earlier reports. Chacko and Rajagopal (1962), Evangeline (1968), Evangeline et al., (1969), Evangeline and Subbiah (1969), Subramanyam and Rao (1970), Evangeline and Sudhakar (1972), Manickam and Srinivasagam (1972), Rajendran and Sampath (1975) and Krishnan and Sampath (1976) have reported an abundance of about 40-55% prawn catch in Pulicat, Ennore, Adyar, Kovalam, Sadras and

Palar estuaries during the years 1960-61, 1963-65, 1965-67, 1966-67, 1966-71, 1971-72. In a recent study, Bose et al., (1978) reported without giving details of the river mouth condition, a higher percentage of 93.5 in the seed abundance in Adyar estuary during September and November, 1976-77. In the absence of any specific information on the condition of the river mouth, it may be presumed that the abundance may be due to the open condition of river mouth.

The pattern of breeding cycle of prawns Penaeus indicus Milne-Edwards recalls the pattern of mullets breeding cycle in that it breeds throughout the year with two peak spawning seasons; one spawning season occurs during September to November and the other occurs during March to May (Panikkar and Menon, 1956 and CMFRI, 1969). The peak spawning seasons of prawns immediately follow the spawning periods of mullets. As in the case of mullets, the abundance of prawn seed in the coastal estuaries may be correlated with the hatching of prawn eggs along the inshore waters of Madras and their subsequent migration into the following estuaries: Pulicat, Ennore, Adyar, Kovalam, Edayur, Sadras and Palar.

Similar relationship may be observed in the case of fry and fingerlings of fishes other than mullets. In this connection, it may be pointed out that the abundance of mullet, prawn and other fish seed occur in succession

Table 59 Catch data of adult mullet, L. macrolepis from Pulicat Lake (From April 1978 to March 1979)

Month	Southern sector wt (kg)	Northern sector wt (kg)	Total wt (kg)	Percentage
April	1134	210	1344	3.75
May	1843	Nil	1843	5.14
June	764	75	839	2.34
July	1190	47	1237	3.45
August	943	404	1347	3.76
September	1245	225	1470	4.10
October	811	Nil	811	2.26
November	752	450	1202	3.35
December	2616	2869	5485	15.31
January	1771	985	3756	10.48
February	3464	4592	8056	22.49
March	3623	4807	8430	23.53
	20156	15664	35820	

throughout the year and this would facilitate exploitation of seed in different periods of the year. The problems that may be faced by juveniles are those of environmental hazards as evidenced by the poor catch of adult mullets (2.26 to 23.53%) from Pulicat lake (Table 59). It is recommended that exploitation of the mullet, prawn and other fish seed may be carried out during the peak periods of abundance and cultivate them under optimal culture conditions for commercial exploitation.

Employability of estuaries for aquaculture

Pritchard (1967) defined an estuary as a semienclosed coastal body of water which has a free connection with the open sea. That the process of cutting off the free connection with the open sea has a greatest effect on the biological aspects of the coastal ecosystem has been pointed out by Odum (1970). As pointed out in the present study, the consequences of keeping the river mouth open are many. Due to the back and forth movement of tidal currents, the estuarine system is "pulse stabilized" and kept in a youthful state with food conditions favourable for the growth of fish seed. In the coastal estuaries of Madras both the extremes of salinity and temperature conditions have been met with (Gopinathan et al., 1974). For instance, during the months of November and December and April and May, minimum and maximum salinity and temperature recorded were 1.04 - 38.29‰ and 25.2 - 32.4 $^{\circ}$C respectively. Physiological adaptations of mullets to cope with extreme salinity and temperature variation are yet another factor for their successful colonization of estuarine habitat (Kinne, 1964, 1970, 1971, 1975 and Kutty, 1967). However, the oxygen regime present in the estuaries impose further conditions for the abundance of the mullets. During the present study, it was found that only in River Cooum huge oxygen deficit was registered. Earlier cage culture studies revealed that Cooum estuary is not suitable for aquacultural experiments, in that high mortality was observed within 24 hours when healthy mullets, *Liza macrolepis*, *Liza dussumieri* and *Mugil cephalus* were cultured in cages (Azariah *et al*., 1980). In other estuaries, the minimum ambient oxygen recorded was 1.62 ml/l which is above the minimum lethal level of oxygen required for the survival of mullets. The effect of low oxygen on the survival and distribution of fishes has been extensively studied both under natural and laboratory conditions (Saad, 1972; Knudson and Belaire, 1975).

The oxygen requirement for fishes in estuaries was reviewed by Doudoroff (1957); Fry (1957, 1971); Doudoroff and Warren (1965), Doudoroff and Shumway (1967) and Alabaster (1972) who have reported that lethal levels may probably be avoided by maintaining dissolved oxygen levels above a level of 2 ml/l. Mackay (1973 a) suggested that this level may be much lower for some species, while other species may tolerate much lower concentrations of dissolved oxygen level for short periods of time. In the absence of information on the minimal oxygen requirements for mullets, the results of the present study may be taken as a base line information for further studies. The asphyxiation level of mullet L. macrolepis was found to be in the range of 0.78 to 0.89 ml/l (results unpublished). Therefore, it stands to reason that the lethal levels for mullet, L. macrolepis may range between 0.75 to 1 ml/l. It is tentatively suggested that if the dissolved oxygen level in estuarine waters of Cooum River and Adyar estuary is maintained above 2 ml/l as has been recorded in other coastal estuaries of Madras, the future prospects of mullet culture may be improved.

In the recruitment and abundance of prawn fry and fingerlings of the species, Penaeus indicus Milne-Edwards, salinity, temperature and dissolved oxygen also play a major role (Gunter, 1950; George, 1962; Gunter et al., 1964; Zein-Eldin and Aldrich, 1964; Venkatramiah et al., 1973 b, 1974; Gopinathan et al., 1974 and Subramanyam, 1974). Since prawns are isoosmotic with estuarine waters, physiological stress imposed by the reduction in salinity may not be great (Reddy, 1962 and McFarland and Lee, 1963). The oxygen requirement for prawns was reviewed by Vernberg (1972) who reported that sublethal levels may be in the range of 3 ml/l. Subramanyan (1962) and Kutty et al., (1971) have reported that the asphyxiation level of prawn, P. indicus is in the range of 1.12 to 1.34 ml/l. These two physiological adaptations appear to favour the recruitment of prawn seed also in estuarine waters.

Estuaries are considered to be areas of high biological stress due to environmental extremes in salinity, temperature and dissolved oxygen regimes (Mackay et al., 1978). The factors that affect the dissolved oxygen levels of the water are (i) changes in freshwater input (ii) tidal range (iii) sewage wastes (municipal and domestic wastes) (iv) agricultural and industrial waste water pollution (v) eutrophication (vi) rain fall (vii) alterations in temperature (Young, 1964; Mackay and Fleming, 1969; Wheeler, 1969; Mackay and Waddington, 1970; Mackay and Gilligan, 1972 b; Smith et al., 1973; Tsai, 1973; Knudson and Belaire, 1975 and Mackay and Leatherland, 1976 a and Mackay et al., 1978). Pritchard (1969) and Mackay and Gilligan (1972 b) have emphasized the interrelationship between the inflow of freshwater laden with high oxygen level, and the retention time of polluted material in the water. There is an inverse relationship between the two. It has been reported that in the estuaries of Madras coast, surplus water from irrigation tank and storm water are let into the river system frequently and more frequently during monsoon seasons. It has been estimated that about 73,000 cusecs of freshwater is allowed to flow into the Adyar river system during the North East monsoon period (TNPWD, Communication-Irrigation Department, 1980). In such circumstances, it is logical to expect a high dissolved oxygen regime in coastal estuary. Since the maximum oxygen level in the coastal estuarine area of Madras does not exceed 4.30 ml/l, it is likely that the oxygen enrichment, consequent to freshwater inflow, is countered by letting in of untreated sewage and industrial wastes. In this connection, it may be pointed out that an estimated amount of 51 million gallons of sewage water/day are being generated in the Madras Metropolitan area, out of which about 1.8 million gallons/day are allowed to flow into Adyar river system (TNWSSB, 1980). Further, an additional amount of about 7,75,000 litres of industrial waste water carrying heavy metallic elements are discharged daily into Adyar river system (Sornavel, 1978). Such antagonistic and anthropogenic sources of oxygen enrichment and depletion is the result of industrialization which has created conditions that are not favourable for long term fish culture.

Another source of oxygen supply is the influence of tidal sea water. Along the Madras Coast, the tidal level ranged from 0.02 to 1.36m during the year 1978-79. For an effective supply of oxygen the mouth of the river must be kept open. As has been suggested earlier, an environment condusive for fish culture can be achieved if effective managemental studies are undertaken in order to control and coordinate the three factors namely i) inflow of freshwater/ sea water, ii) the retention time of pollutants and iii) the open condition of the river mouth. Surveillance work carried out by the Tamil Nadu Public Works Department (Irrigation) in keeping the river mouth open and the concomitant increase in fish seed yield, as reported in the present study, may be taken as an initial promise of high degree of success that can be achieved in this direction if such coordinated environmental management of coastal estuarine system is carried out.

Use of sewage fertilized water for aquatic production has yielded significant results in terms of the yield of fish (Hora, 1944; Allen et al., 1958; Wolny, 1962; Feinmesser, 1963; Allen, 1969, 1972 and Trimberger, 1972). Experiments carried out in the United States have shown higher growth rates of cat fishes in aquatic ecosystem involving the utilization of sewage effluence (Huggins and Backmann, 1969 and U.S.A. 1970). Further, brackishwater impoundments have been deliberately fertilized to increase fish production in some of the West European countries (Raymont, 1949; Buljan, 1961

Shelbourne, 1964 and Bowers, 1966). Bose (1944) found that the ability to rear fish in sewage stabilization ponds in Calcutta was greatly hampered because of insufficient water to mix with the raw or partially processed effluents. In the case of estuaries of coastal Madras, flushing the system with fresh water as well as letting in of limited amount of sewage are factors that may help to overcome the problem encountered by Bose (1944). As a result, an intermediate status between the highly eutrophic stressed natural environment and the highly controlled laboratory situation may be achieved for favourable fish production.

Further, Alikunhi (1957) reported that in natural fish ponds, Cyprinus carpio showed a growth rate of 50 mm/month. Muthuswamy (1973) and Muthuswamy et al., (1974) have indicated that Cyprinus carpio attained the average length of 130 mm/month in the sewage stabilization ponds. Muthuswamy et al., (1978) have reported that in sewage effluent ponds, Cyprinus carpio attained the average length and weight of 327 mm and 656 gm after 206 days of culture in a polyculture system. They further reported that the average length and weight of Labeo fimbriata increased to 288 mm and 299 gm respectively. The average length and weight of Labeo rohita were found to be 297 mm and 297 gm. The average length and weight of Cirrhina mrigala were found to be 390 mm and 612 gm after 206 days. Since no supplemental feeding was given during the above study, it follows then that increased fish biomass should have resulted from the organic constituents of the sewage system.

Moreover, organisms under culture conditions develop special behavioural, physiological and biochemical adaptations to overcome the range of variation in the environmental factors at the culture site (NIO, 1980). The results obtained in the present study provide supporting evidence for the existence of a condition referred to above. Farm mullets showed an increased growth of 17 mm/month over the natural population where the observed increase was only 13 mm per month. In this connection it may be pointed out that previous workers have recorded a growth rate of 12 mm. In attempting to find out possible causes for the increased growth under culture conditions the following hypothesis may be put forward. From an ecological standpoint, the estuarine ecosystem is highly productive, since it is kept young and relatively unstable than the older system (Odum, 1969). In the case of coastal estuaries of Madras, the system will be kept young, when the river mouth is in constant continuity with the sea coast. Foyn (1965) pointed out that oxygen depletion caused by waste disposal in the estuarine areas as a limiting factor in the distribution of fish. However, reaeration of water by tidal currents may eliminate dissolved oxygen functioning as a limiting factor. Observations made by Pentelow (1961) have indicated that although sewage discharge can produce short term harmful effects, the long term beneficial effect of sewage discharge on fishing may be achieved with the proper care of the ecosystem. Studies have indicated that sewage disposal in coastal embayments causes an increase in primary and secondary production with a decrease in species diversity (Patrick and Strawbridge, 1953; Copeland, 1967 and Ryther and Dunstan, 1971). Therefore, it would seem that both dissolved oxygen and food conditions may not serve as a limiting factor to the fish seed during the initial stages of colonization. The non-availability of adult fish in abundance may be one of suceptability of adult fishes to prolonged environmental stress leading to an decrease in species diversity (Gray, 1979). In the case of Cooum estuary such a decrease in species diversity has been noticed (unpublished results). It may be inferred that although sewage let into an estuarine ecosystem may favour the colonization of estuarine coast by the mullets due to food security and physiological capabilities of mullets, a close study may reveal that a third factor namely the letting in of industrial effluents carrying heavy metals may play a significant role in affecting the colonization of mullet seed. It is known that heavy metal toxicants like mercury and cadmium have an adverse effect on the survivability of fishes.

In the local context, it has been pointed out that an estimated amount of 7,75,000 litres/day of industrial effluents is let into the Adyar estuary, Madras. Studies on the bio-accumulation of mercury (in gill-0.10 ppm, liver-0.09 ppm and muscle-0.12 ppm) and cadmium (in gill-0.94 ppm, liver-0.78 ppm and muscle-1.55 ppm) in Liza macrolepis (Smith) have indicated higher amounts of metal localization than normal. Therefore, despite food and dissolved oxygen security elevated levels of heavy metals may adversely affect the survivability of mullets both in the natural environment as well as under culture conditions.

Interestingly enough, Musani, et al., (1980) studied the role of chelation of toxic metals by humic acid, both of marine and estuarine origin. Using high voltage paper electrophoretic technique they observed that the amount of humic material dissolved in the open sea are too small to contribute significantly to the chelation of zinc, cadmium, lead and bismuth, while in estuarine waters, the contribution of humic acid to trace metal chelation is quite significant. Considering the ecological, physical, geographical and biotic background of the field culture conditions it is seen that litter production by the shrubs (Cassia occidentalis Linn., Lantana camara Linn., Spathodea campanulata Beaur and Bogainvillea arbortristis Linn.) and trees (Delonix regia Raf., *Tamarindus indica*., *Morinda tinctoria* Roxb., *Prosopis juliflora* Roxb., *Enterolobium samam* Prain., *Cassia fistula* Linn., *Azarirachta indica* A.Juss., *Thespesia populnaea* Cav., *Acacia arabica* Willd., *Mangifera indica* Linn., and *Avicennia afficinalis* Lin.) growing along the banks of the River Adyar may accelerate the formation of humic acid in the estuarine waters. It is likely that some portion of the heavy metal toxicants may be detoxicated in the natural system by the process of trace metal chelation by humic acid.

It is suggested that in future, more applied studies may be carried out on the interrelationship between the fertility due to sewage and control of heavy metal toxicants by chelation together with the environmental stress imposed by the synergestic effect, if any, between sewage pollution and deleterious effects of heavy metal toxicants.

The fate of heavy metal contaminants, after they are absorbed in the body of aquatic organisms, has been a subject of much study. It is known that in fishes, a combination of physiological processes such as absorption, excretion and storage may be capable of regulating the concentrations of heavy metals in the body despite changes in their availability in the aquatic environment (Bryan, 1971). Bryan (1968, 1976 a) reported that the removal of contaminants may occur in fishes through faeces, urine, via liver and gall bladder. He observed that in decapod crustaceans, zinc and copper are regulated but he found no evidence for the regulation of non-essential metals such as mercury and cadmium. In fishes, it has been established that muscle is able to regulate levels of zinc and copper. Furthermore, Benoit *et al.*, (1976) elegantly established the regulation of cadmium in the muscle of trout, *Salvelinus fontinalis*. On the other hand, Mckim *et al.*, (1976) reported that methyl mercury is not regulated and the ability of fishes to excrete methyl mercury is rather limited (Pentreath 1976 c). In the body of fish, mercury is found in the methyl form and is more toxic. Experiments with 203 Hg - labelled methyl mercury have shown that fishes such as *Fundulus heteroclitus* and *Salmo gairdneri* can demethylate the toxic methyl mercury (Renfro *et al.*, 1974 and Olson *et al.*, 1978). Bryan (1979) suggested that demethylation and consequent storage may occur in the liver of fishes.

The results reported in the present study agree with the general pattern of biological responses of fishes to non-essential metals (mercury and cadmium) in that different tissues of mullet *Liza macrolepis* (Smith) accumulate varying amounts of mercury (in gill-0.10 ppm; liver-0.09 ppm and muscle-0.12 ppm) and cadmium (in gill-0.74 ppm; liver-0.78 ppm and muscle-1.55 ppm). The fact that the concentration of cadmium is lesser than other metals (see section 3.7.0) may provide suggestive evidence for the presence of regulation of cadmium by *L. macrolepis* has has been established in the trout, *Salvelinus fontinalis* (Benoit *et al*., 1976). The elevation of mercury accumulation in the liver tissue may support the contention of Bryan (1971) that toxic methyl mercury may be demethylated and consequent storage may occur in the liver tissue. Such an inference is in agreement with the report of Bryan (1979) who suggested that species of marlin, *Neothunnus albacora* have the capacity to demethylate methyl mercury like marine mammals.

Another aspect of interest is the increase in the concentration of mercury in the muscle of *L. macrolepis* under laboratory test conditions with increasing time. A study of the variation in slope function may suggest the susceptibility of individuals, consequently as that of the population, to the stress conditions. In both the cases of test conditions involving mercury and cadmium, a decrease or a plateau formation after a period of 48 h treatment was observed which may indicate that some degree of detoxification or/and regulation that may take place in the body of *L. macrolepis*. The fact that the slope function shows a marked increase after a period of 72 h may indicate the demethylation of methyl mercury may be hampered beyond a threshold value. Under these circumstances, *L. macrolepis* may succumb to the heavy metal stress. In the mullet Liza macrolepis, it is found that bioaccumulation of heavy metals such as mercury, cadmium, copper, zinc, nickel, lead and iron is less in the muscle tissue than in gill and liver tissues. The difference in accumulation patterns of these metals among the three tissues may be related to differences in the pattern of uptake and elemination rates of metals (Cross *et al.*, 1973). The results of the present study substantiate the above suggestion that muscle tissue accumulated only 0.80 ppm of mercury and 0.56 ppm of cadmium while the gill accumulated 4.70 ppm of mercury and 5.23 ppm of cadmium. Liver tissue accumulated 30.10 ppm of mercury and 0.72 ppm of cadmium at 96 h Lc 50 concentration.

The concentration factor (CF) for the muscle tissue worked out to be 2.22 for mercury and 0.19 for cadmium. On the other hand, the concentration factor for gill tissue was as high as 13.05 and 1.78 for mercury and cadmium respectively. In the case of liver, highest concentration factor for mercury was recorded which amounted to 83.61. With regard to cadmium a CF of 0.24 was obtained. It is likely that such differences may be due to differential regulatory effect of the tissue. That muscle tissue may exhibit more regulatory ability was shown by Benoit *et al.*, (1976) who found that regulation of the cadmium in the muscle of trout Salvelinus fontinalis. However, Mackim *et al.*, (1976) have found that methyl mercury is not regulated and the ability of fishes to excrete methylmercury is rather limited (Pentreath 1976 c). Eisler et al., (1972) have reported that in Scallop Aquipecten irradians and lobster, Homarus americanus, the accumulation of cadmium in muscle found to be less. In the case of mullet, Liza macrolepis (Smith) it is likely that the elimination of cadmium may equal to uptake rate. Some evidence that such an equalization may occur in fishes may be seen in the works of earlier authors (Friberg et al., 1971; Eisler et al., 1972 and Greig et al., 1974). The elimination of mercury by fish and other aquatic animals have been reported earlier by Miller et al., (1961); Wallace et al., (1971); Miettinen et al., (1972); Keckes and Miettinen (1972); Tillander et al., (1972) and Burrows and Krenkel (1973). Further, Cross et al., (1973) have reported that accumulation pattern of trace metal in fish muscle can vary as a function of the species of the fish, its size and the behaviour of the metals. Therefore it is proposed to study in the near future the possible mechanism of detoxification in these fishes. It has been pointed out by Bryan (1979) that there may be many types of mechanisms which may vary according to different species. The storage of mercury as mercuric selenide by black marlin and the accumulation of metals in granules by various invertebrates (Martoja and Viale, 1977) undoubtedly warrant further study on detoxification and other protective mechanisms existing in fishes.

The consequences of bioaccumulation of mercury in one trophic level has many consequences. It has been pointed out that there may be bioamplification of mercury levels in the food chain from invertebrates to fishes (Knauer and Martin, 1972 and Letherland et al., 1973). Therefore, high health risk is involved if mercury is bioaccumulated. It is not known whether mercury can be detoxificated in the natural environment by the process of metal chelation of humic acid (Mantoura et al., 1978 and Musani et al., 1979, 1980). Further, heavy metals may be kept out circulation by absorbing to sediments. Such sequestal contaminants may be recycled through detritus feeders. It will be of interest to study such natural process from the standpoint of survivability of fishes in the Adyar River environments polluted with mercury.

As a remedial solution, it may be suggested that heavy metal contaminants and their offensive nature of the putricible organic matter brought along with the sewage may be diminished by dispersion due to sufficient dilution enabling the river system to accomplish self-purification(Lenhard, 1965; O'Sullivan, 1971; Weidemann and Sendner, 1972; Castillo, 1973 and Gundelach and Castillo, 1976). In this process, it is imperative that the river mouth must be kept open if the above purpose is to be achieved. The other processes involved in self-purification are: reduction, oxidation and sun light (Streeter and Phelps, 1925; Sundaresan, 1957; Govindan, 1958 and Odum, 1967).

Among the biological processes that favour self-purification processes such as the devouring action of bacteria on organic matter, algae giving oxygen during photosynthesis and protozoans feeding on bacteria are the sub-systems that has to be developed in the estuarine and coastal embayments from the standpoint of sanitary engineering (Sundaresan, 1957; O'Sullivan, 1971 and Castillo, 1973). If favourable conditions are provided in the estuarine ecosystem, toxic heavy metals such as mercury and cadmium may be naturally detoxificated by the process of self-purification. It is suggested that in this context, a knowledge of safe level concentration is essential in enforcing a threshold concentration of toxicant where there can be optional self-purification.

The literature is replete with biological responses of marine animals to various heavy metals toxicants. Such biological responses differ under acute and sub-lethal conditions. It is known that in fishes living within the safe level concentrations, reproductive effectiveness in fecundity and successful fertilization of the eggs, hatching, feeding and growth are found to be normal or near normal conditions. In this context, the contribution of the present work in obtaining a clear picture of 'safe level concentration' is of great practical importance and of economical value. It is suggested that continuous and periodical monitoring may provide us with information as to when exactly the system is brought under stress and when preventive measures are to be undertaken. In this context, it may be suggested that mullet, Liza macrolepis (Smith) with its limited heavy metal regulation and differential accumulation of metal may serve as a suitable bioassay material in heavy metals monitoring studies.

It is well documented that pollutant induced alterations in behavioural pattern occur in organisms. Such behavioural responses of marine poikilotherms may be used as an yardstick for water quality. In the study of behavioural toxicology, physiological responses such as changes in respiration, migration, intraspecific visual attraction, predation vulnerability, swimming performance and avoidance response have been used in the formulation of water quality standards (Eisler, 1979). In the absence of detailed work on the behavioural toxicology of fishes in Indian waters, the results of the present study provide basic information for using behaviour as a diagnostic character in pollution biomonitoring programmes.

In mullet, Liza macrolepis (Smith) the other effects that are evident before the loss of equilibrium leading to death are: (i) increased opercular movements (ii) swimming activity and (iii) disruption of the respiratory processes. The opercular beats were increased by a factor of four times when subjected to an acute mercury concentration at 96 h

Lc 50 level. Similarly, the frequency of coming to the surface of water was also enhanced. Such a change in the opercular rate and swimming activity are sensitive indicators of physiological stress in *L. macrolepis*. In *L. macrolepis* under acute conditions, the increased opercular rate may be caused by decreased efficiency in oxygen uptake. The stress imposes by heavy metals involve an initial increase in metabolic rate which has been termed as the 'overshoot response' (Kinne, 1967). Such a sudden increase in metabolic rate may indicate a change in the energy requirements for coping with the entry of the pollutant. In this context, it may be recalled that 'detoxification' processes may be operative in *L. macrolepis* as has been indicated by the changes in the slope function. The short-term response as shown by changes in the slope function and an attempt to 'pumpout disorder' as indicated by the increased energy requirements may appear adaptive for species survival. However, energy requirement for longer periods of time may result in a reduction of life expectancy. As noted in the present study, the efficiency in oxygen uptake has been considerably decreased in those mullets, which collapsed during the course of the experiment. Such a feature is accompanied by other morphological and histopathological changes such as fin erosion, destruction of different types of cells in the gill lamellae, fusion of epithelial cells of secondary gill lamellae, interlamellar debris, rupture of hepatic cells of the liver, necrotic changes, enlargement of parenchymal cell vacuolation, disruption in muscle bundles, lack of striations and constrictions and atrophy of muscle bundles. Supportive evidence may be derived from the biochemical analyses of tissues (gill, liver and muscle), where it is found that changes in the protein fractions appear to be very common. These changes include alterations in the mobility of the fractions as well as disappearance of the bands. Further, weakening in the intensity of bands may be the manifestations of physiological and biochemical effects of the pollutant stressors. Wedmeyer and Yasutake (1977) tentatively identified a partial clinical profile of biochemical responses in fish during acute or chronic stress. McLeay and Brown (1979) have observed that in juvenile coho-salmon, Oncorhynchus kisutch, elevated plasmo glucose, lactate levels and depressed liver, muscle glycogen levels are consistent with this incomplete profile for chronic stress. In the light of the foregoing reports, the work of McLeay and Brown (1974) appear significant. They have reported a decrease in body protein content besides an increase in the glycogen content of the liver and muscle tissues. Similar biochemical responses were observed in Cohosalmon, Oncorhyncus kistuch (McLeay and Brown, 1974). It is likely that in L. macrolepis also, the decrease in liver and body protein may be accompanied by elevation in glycogen level. Such a suggestion may support the increased oxygen demand subsequent to the exposure to pollutants.

Sindermann, et al., (1978) and Sindermann (1979) while reviewing the environmentally induced abnormalities in fishes drew attention to site specific fin erosion. Erosion can be localized in the middorsal and anal fins or it can be a "generalized" erosion affecting broad areas of several fins. Besides, fin erosion, epidermal lesion and removal of the protective mucous coat may be noticed. In the present study, a few mullets, about 7.08% of total catch, inhabiting the Adyar estuary were found to show the above symptoms (Nammalwar, 1981). The fin rays showed splitting of fin membrane leading to hemorrhaging of fin tissues. In some cases, total loss of fin rays tips were observed. Such a syndrome of fin erosion in L. macrolepis may be associated with the sewage and industrial wastes. In this connection two factors may be mentioned. It has been reported that heavy metals may be sequested with the sediments. That the sequested heavy metals may induce fin erosion was established by Sherwood (1976) who fed the Dover sole Microstomus pacificus, under laboratory conditions, with sediments obtained from highly polluted areas. Such fishes exhibited fin erosion disease as that of the fishes caught in the natural environment (Mearns and Sherwood, 1976).

It is likely that in Adyar estuary heavy metals may be sequested with the sediments and may be transferred through the sediments or/and passed on through the food chains to the adult mullets *L. macrolepis*. Since about 1.56 to 7.08% of *L. macrolepis* in Adyar estuary were found to show fin erosion diseases (during 1978-79), it provides circumstantial evidence that Adyar estuary is being polluted with heavy metals. It is recommended that remedial measures be implemented soon.

It is known that oxygen uptake in poikilotherms may be used as an 'index' of metabolic activity (Prosser, 1975; Hughes, 1976). In recent years, many workers have attempted to relate the metabolic responses of fishes with the quality of the water (Belding, 1929; Jones, 1947; Doudroff, 1957; Schaumburg *et al.*, 1967; Pickering, 1968; Skidmore, 1970; Cairns *et al.*, 1970; Spoor *et al.*, 1971; O'Hara, 1971; Heath, 1972; Waller and Cairns, 1972; Nielson, 1974; Morgan and Kuhn, 1974; Sldof, 1979 and Singh and Singh, 1979). In such works, the increase/decrease in oxygen uptake was found to bear a close relationship with the build up of heavy metal toxicants. In reviewing the work on different metabolic responses of fishes to heavy metal toxicants, three broad categories may be outlined. In the first category, fishes show an immediate "over-shoot response" and then continued to exhibit erratic pattern of response (Jones, 1947; Matthiessan and Brafield, 1973 and Brafield and Matthiessan, 1976). Secondly, the initial shock leading to high rate of oxygen uptake is maintained for a period of 24 h and finally the fishes succumb to stress (O'Hara, 1971). Thirdly, after initial increase there is a gradual decline in oxygen consumption approaching the normal pattern of oxygen uptake (Premadas and Amderson, 1969 and Singh and Singh, 1979). Matthiessan and Brafield (1973) and Brafield and Matthiessan (1976) in their work on sticklebacks, *Gasterosteus aculeatus* found an initial increase followed by erratic pattern of oxygen uptake when exposed to acute zinc concentrations. Such fishes invariably died at the end of experiment. In fishes, such as blue gills, *Lepomis macrochirus* the initial high amount of oxygen uptake was maintained for a long period (O'Hara, 1971). The work of Singh and Singh (1979) indicated that the initial increase in oxygen uptake may be brought low to that of the normal conditions after a period of 168 h. On this basis Bryan (1979) classified the fishes into two groups: (i) those that regulate the amount of incoming heavy metal toxicants and (ii) those that succumb to the stress of toxicants.

In the present study, the respiratory pattern of *L. macrolepis* appear to be a combination of patterns I & II in that in some fishes, the initial high respiratory rate was maintained for a period of 24 h and continued thereafter till 96 h, while in others, there were instances of sharp fall in the rate of oxygen uptake. The changes in the slope function may indicate the existence of regulatory activity in the fish after a period of 48 h. It is likely that the continued enhanced rate of oxygen uptake in *L. macrolepis* may provide circumstantial evidence for its attempts to regulate the build up of heavy metals in its body. It is likely that when the stress exceeded the threshold level, the fishes may succumb to death.

There is a large body of literature documenting the histopathological changes induced by the mercury compounds. The work of Wobeser (1975) indicated that various mercury compounds exert varying degrees of cellular damage. Mercuric chloride caused severe necrosis, while methyl mercury resulted in hyperplasia with greatly increased mitotic figures (index),degeneration and terminal desquamation of epithelium. All these changes result in death due to asphyxia. Many other works have provided documentary evidence that death in fishes, in acute poisoning of heavy metals, is due to disruption of the respiratory processes caused by the damage of gill epithelium (Thomas, 1915; Carpenter, 1927; Jones, 1938; Schweiger, 1957; Lloyd, 1960;

Skidmore, 1964, 1970; Amend et al., 1969; Baker, 1969; Flick et al., 1971; Skidmore and Tovell, 1972; Chapman, 1973; Eisler and Gardner, 1973; Wobeser, 1975; Tafanelli and Summerfelt, 1975 and Gardner, 1975). An interesting feature is that the apparent increase in the number of cells in mitosis is due to mercury compounds was reduced greatly when fishes were transferred to clean water (Wobeser, 1975). He suggested the existence of repair mechanisms concerned with the restoration of normal histological situations In the case of *L. macrolepis* (Smith), when subjected to acute poisoning of mercury, the observed histopathological changes are similar to those described by earlier authors (see section 3.5.0 for details). In the light of the above observation, it would appear that if the river water is cleaned periodically by the ebb and flow of the tides, such a repair mechanisms may be effective in lengthening the longivity of fishes.

Similarly the histopathological changes observed in the gills of mullets, consequent to the exposure to cadmium recall similar observations made by earlier workers (Gardner and Yevich, 1970; Eisler, 1971; Bilinski and Jonas, 1973; Newman and MacLean, 1974; Gardner, 1975 and Voyer et al., 1975). The interlamellar debris and merging of the epithelial cells are diagnostically significant in *L. macrolepis*. Skidmore (1970) suggests that such a condition may lead to tissue hypoxia.

Many workers have reported histological lesions in the liver of various fishes exposed to mercury and cadmium (Pickering and Henderson, 1966 and Baker, 1969). Recently, Ribelin and Migaki (1975) have reviewed the histopathological changes in the liver of fishes exposed to heavy metals. Histopathological lesions such as enlargement of the hepatic cells, enlargement of parenchymal cell vacuolation and degenerative changes were also recorded in *L. macrolepis*. Further, cellular damage in the liver due to the accumulation of heavy metals, would lead to a significant reduction in the life expectancy of *L. macrolepis*.

An interesting situation is obtained in the case of muscle tissue of mullets exposed to mercury and cadmium. Atrophy of muscle bundles, disruption with discontinuity of striations, contraction of the muscle bundles, alterations in the banding pattern and proliferation of nuclei appear similar. It is interesting to note that pathological changes in the muscle are less when compared to gill and liver since the bioaccumulation levels of these metals in the muscle is found to be less than the other two tissues. This would suggest that the resistance/regulation capacity of the muscle tissue is relatively greater. Supportive evidence may be derived from the results of electrophoresis, in which biochemical changes consequent to the exposure of mullets to mercury and cadmium is relatively meagre.

Stress responses are intimately involved in the resistance of fish to disease and in their ability to adapt to pollutants (Brett, 1958; Snieszko, 1974; Wedemeyer et al., 1976; Mayer et al., 1978). Therefore, the biochemical and physiological responses characteristic of both acute and chronic stress as well as the influence of these responses on the well being of the fish and its changes for survival in the natural environment should be clearly defined.

In fishes, the biological consequences of exposure to a toxic heavy metal such as mercury and cadmium can be demonstrable at biochemical level well in advance of observable behavioural changes (Mckim et al., 1970; Gould and Karolus, 1974; Acke Larsson et al., 1976; Sharma and Davis, 1980 and Gill and Pant, 1981). Sharma and Davis (1980) have reported that protein degradation in the liver of carp *Cyprinus carpio* is inhibited by the effect of methylmercury which inhibit protein synthesis. Gill and Pant (1981) have reported that the glycogen levels in liver and brain in carp, *Cyprinus carpio* was inhibited by sublethal concentration of mercury. Gould and Karolus (1974) observed a reduction in the rate of protein synthesis in various tissues of the gunner, *Tautogolabrus adspersus* when exposed to 96 h Lc 50 levels of cadmium. Further Gray and Mckenzie (1970) have stated that protein pattern in the muscle of fishes is not influenced by inherent factors like sex, stage of maturation and geographical location. Therefore, the alterations in the protein patterns that are noticed in the present study may be due to the influence of exogenous factors like toxic environment as has been suggested by Castell *et al*., (1970). Observed reduction in protein level of *L. macrolepis* may therefore, be a direct consequence of the stress imposed by mercury and cadmium. Therefore, as has been pointed out earlier, early remedial solution in terms of an effective and integrated ecological management of the coastal estuaries must be sought in order to restore a normal 'pulse stabilization' of the estuaries.

5.0.0 SUMMARY

5.1 A survey was undertaken for a period of one year from April 1978 to March 1979 in the following eight estuaries: Pulicat, Ennore, Cooum, Adyar, Kovalam, Edayur, Sadras and Palar. The aim of the study was to assess the regional, seasonal and specieswise abundance of cultivable mullet, *Liza macrolepis* (Smith), prawn, *Penaeus indicus* Milne-Edwards and other fish seed resources.

5.2 Based on the results, the following four estuaries namely Adyar, Ennore, Palar and Pulicat have been considered as potentially good grounds for seed collection.

5.3 The patterns of seasonal percentage composition of mullet, *L. macrolepis* and prawn, *P. indicus* and other fish seed from all the eight estuaries have been assessed.

5.4 There was an inverse relationship between the occurrence and abundance of mullet and prawn surveyed in all the eight estuaries.

5.5 Maximum percentage abundance of mullet seed was recorded during the month of May (56.18) in Pulicat; during December (68.25) in Ennore; during May (66.66) in Cooum; during February (96.34) in Adyar; during November (91.88) in Kovalam; during June (84.67) in Edayur; during June (10.53) in Sadras and during December (90.53) in Palar estuaries.

5.6 Maximum percentage of prawn seed was recorded during the month of November (90.09) in Pulicat; during November (43.87) in Ennore; Nil in Cooum; during September (93.78) in Adyar; during June (35.36) in Kovalam; during February (17.08) in Edayur; during July (84.35) in Sadras, and during November (54.24) in Palar estuaries.

5.7 Maximum percentage abundance of other fish seed was recorded during August (73.86) in Pulicat; during May (91.26) in Ennore, during January (96.38) in Cooum; during July (80.22) in Adyar; during September (98.85) in Kovalam; during August (97.39) in Edayur; during January (93.17) in Sadras and during April (93.55) in Palar estuaries.

5.8 Seasonal variation in the distribution patterns of various size groups showed that mullet and prawn fry and fingerlings of the length group 10-34 mm occurred throughout the year in all the eight estuaries.

5.9 From the seasonal abundance of fry and fingerlings of mullets and prawns, it was inferred that mullets and prawns breed throughout the year with two peak spawning seasons which occur between April and June & October and December. This information provided supportive evidence for the earlier reports.

5.10 Hydrological parameters such as temperature, salinity, dissolved oxygen, p^H and water transparency were monitored from April 1978 to March 1979 in the eight estuaries mentioned earlier. Seasonal variation in the above parameters was correlated with the distributional abundance of the seed resources.

5.11 Meteorological parameters such as air temperature, relative humidity, rain fall, sunshine and wind speed were reported for the period from April 1978 to March 1979.

5.12 It was found that due to the recent managerial work of Tamil Nadu Public Works Department (Irrigation) some improvement in the fish seed resources has been observed. An increase of 50-55% mullet and prawn seed abundance has been registered in the estuaries of Adyar, Ennore, Palar and Pulicat.

5.13 In assessing the ecological significance of the results, it is proposed that the abundance of mullet, prawn and other fish seed resource in some of the estuaries may be increased if the mouth of the estuaries are kept open throughout the year.

5.14 Aquaculture experiments on the growth rate of mullet *L. macrolepis* under field conditions in Adyar estuary showed an increase in growth rate when compared to natural population. Culture experiments showed that neither stocking density nor cage size had any bearing on the growth rate.

5.15 Field bioassay tests conducted in Adyar estuary revealed a direct relationship between the survival rate of mullet, *L. macrolepis* and condition of the river mouth. It was found that the survival rate decreased with the closure of the mouth of the Adyar estuary.

5.16 In comparison, the River Cooum estuary was found to be more polluted than Adyar estuary. Zero survival rate was observed within 1½ hours when the tide was low. When the experiment was conducted during high tide period, the zero survival rate was observed in about 5½ hours time. Rapid deoxygenation of the medium due to high organic load has been considered as the major cause of death.

5.17 The ecological impact of releasing the untreated sewage water into the Cooum and Adyar estuaries has been commented upon.

5.18 Hydrological factors such as temperature, salinity, dissolved oxygen, p^H and water transparency were monitored in Adyar and Cooum estuaries during the period when field bioassay/aquaculture experiments were conducted from January to July 1980.

5.19 Meteorological parameters such as air temperature, relative humidity, rain fall, sunshine and wind speed were collected for the period from January to July 1980.

5.20 Acute toxicity tests for 96 h period was carried out for mullet, L. macrolepis exposed to mercury and cadmium so as to determine the median lethal concentration (Lc 50) as recommended by Litchfield and Wilcoxon. Accordingly 96 h Lc 50 value of mercury and cadmium to mullet, L. macrolepis were estimated to be 360 ppb and 2940 ppb respectively.

5.21 Based on the changes in slope function, the existence of a regulatory/detoxification mechanism in mullet L. macrolepis between 48 and 72 h after exposure to mercury and cadmium has been inferred.

5.22 A review on the different factors used as 'application factors' to extrapolate the 'safe level' concentrations has been given. Using 0.10 to 0.55% of 96 h Lc 50 concentrations of mercury and cadmium as application factor, the safe level concentration of mercury and cadmium in Adyar estuary with reference to mullet, L. macrolepis has been evaluated.

5.23 The 'safe level' concentrations of mercury and cadmium for mullet L. macrolepis was found to be 36 ppb and 294 ppb respectively, which are presumably harmless and acceptable 'safe level' concentration. The application factor of 0.10 recommended by Tarzwell, Sprague and Eisler was used.

5.24 It is recommended that continuous monitoring may be made both in the Adyar and other neighbouring estuaries in order to regulate the inflow of sewage and industrial wastes and to limit the level of mercury and cadmium within the estimated 'safe level' concentrations.

5.25 Experiments on behavioural toxicology indicated that responses such as swimming performance, number of visits to water surface and opercular beats of L. macrolepis at 96 h Lc 50 levels of mercury and cadmium were found to be affected.

5.26 Histopathological changes in gills, liver and muscle tissues of mullet, L. macrolepis at 96 h Lc 50 levels of mercury and cadmium were assessed. Gill tissue was found to be affected more when compared to other tissues.

5.27 Studies on the respiratory physiology of mullet *L. macrolepis* at 96 h Lc 50 levels of mercury and cadmium have been made. The respiratory responses of mullets were grouped under three categories. In category I, there was an immediate overshoot response followed by an erratic pattern of response. In category II, mullets showed high rate of oxygen uptake upto a period of 24 h and finally succumbed to stress. In category III, after an initial increase in respiratory rate, there was a gradual decline in oxygen consumption, approaching the normal pattern of oxygen uptake. In general, there was an overshoot response when mullets were exposed to mercury and cadmium.

5.28 Quantitative changes in protein have been observed, when mullets were exposed to 96 h Lc 50 levels of mercury and cadmium. Electrophoretic analysis showed changes in the mobility of protein fractions as well as the disappearance of particular fractions. It is inferred that continuous exposure of mullets to mercury and cadmium may affect the protein metabolism.

5.29 Implications of letting in industrial waste water have been assessed with reference to mercury and cadmium. The distribution and concentrations of heavy metals such as mercury, cadmium, copper, zinc, nickel, lead and iron in the gills, liver and muscle tissues of natural populations of mullet, L. macrolepis inhabiting Adyar estuary, Madras were assessed.

5.30 Based on the degree of concentrations of heavy metals, they were ranked according to the descending order of concentration.

Gill: Fe (163.72 ppm) > Zn (55.21 ppm) > Ni (19.87 ppm) > Pb (2.83 ppm) > Cu (1.63 ppm) > Cd (0.74 ppm) > Hg (0.10 ppm).

Liver: Fe (170.18 ppm) > Zn (76.68 ppm) > Cu (8.19 ppm) > Ni (3.61 ppm) > Pb (1.51 ppm) > Cd (0.28 ppm) > Hg (0.09 ppm).

Muscle: Zn (47.15 ppm) > Fe (12.75 ppm) > Ni (2.45 ppm) > Cd (1.55 ppm) > Pb (1.25 ppm) > Cu (0.60 ppm) > Hg (0.12 ppm).

5.31 Bioaccumulation of heavy metals, mercury and cadmium by gills, liver and muscle tissues of mullet L. macrolepis at 96 h Lc 50 levels have been assessed.

5.32 Variations in the water content of gills, liver and muscle tissues of mullet, *L. macrolepis* before and after exposure to 96 h Lc 50 levels of mercury and cadmium were observed.

5.33 Suitability of using mullet *L. macrolepis* as bioassay material in heavy metals pollution monitoring has been discussed.

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ABSTRACTS

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A short note of the Biometry of *Nemipterus japonicus* (Bloch) in Relation to Sex in Porto-Novo waters*.

The secondary sexual characters are present mostly in the animals of higher order, exceptionally this can be traceable to *Nemipterus japonicus* (Bloch), a bony fish belonging to Nemipteridae family of order Perciformes.

Porto-Novo (C° 11 29°N, 79° 49°E) has a fairly rich fauna of fish and almost all the economically important food fishes of Indian coastal waters are represented here. Seasonal occurrence of *Nemipterus japonicus* in Porto-Novo waters are in abundance from October to February. In the remaining months they make sporadic appearance contributing little value to the commercial catch. The fish appears in shoals during August and September in Indian coasts[1]. Detailed investigations regarding the biometry and biology of this species in Indian waters are very limited.[2-4]

One hundred and eight fishes—both males and females (ratio 1 : 1) were collected and measured separately, from the commercial catches of Pudupettai landing centre, 3 Kms. from Porto-Novo (Near Pondicherry, S. India).

The following parameters : (1) Total length, (2) Fork length, (3) Head length, (4) Body length, (5) Snout length, (6) Snout to Dorsal fin, (7) Dorsal fin length, (8) Snout to Pectoral fin, (9) Snout to Pelvic fin, (10) Snout to Anal fin, (11) Length of upper caudal fin ray, (12) Width of the body, (13) Depth of the body and (14) Diameter of the eye were measured in relation to standard length separately in both the males and females. Standard length of the fish was used as a basic prerequisite against which regression curves for other parameters were drawn.

Out of fourteen parameters measured separately for both the males and females of *Nemipterus japonicus* in the present study, the length or prolongation of the upper caudal fin ray showed a remarkable distinct character. In males the upper caudal fin ray was more elongated (approximately 1½ to 2 times based on 108 males and females) in males than females.

Representative regression curves showed the tangent value for males 0.088 and females 0.035 indicating a faint semblance of external secondary sexual characters present in *Nemipterus japonicus* akin to the animals of higher order. Further this external secondary sexual characters were well developed and could be well seen in matured specimens of *Nemipterus japonicus*.

The other parameters did not show much significant differences in males and females of *Nemipterus japonicus* in the present study. All these parameters have been statistically worked out and found to be significant.

The work was carried out at the Department of Marine Biology, Annamalai University under the guidance of Prof. R. V. Seshaiya, Retd. Director, Marine Biological Station (Annamalai University), Porto-Novo, to whom the author is grateful for facilities and guidance.

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A NOTE ON DETERMINATION OF AGE FROM SKELETAL STRUCTURES OF *POMADASYS HASTA* (BLOCH)

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A NOTE ON DETERMINATION OF AGE FROM SKELETAL STRUCTURES OF *POMADASYS HASTA* (BLOCH)

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Some skeletal stuctures like vertebrae, palatine, cleithrum and operculum appear to be useful in the determination of age of *P. hasta*. These parts have been found useful in determining age of fish by Hart (1950) Menon (1950) Pantulu (1961) and others. Le cren (1947) and Gosline (1960) studied the growth rings on bones for determining the age and growth rate of percoid fishes. An inherent physiological rhythm as a causative factor in the formation of growth checks has been suggested by Menon (1953). Preliminary observations in this regard were made on *Pomadasys hasta* and the results are reported here.

The material was collected from Sassoon Dock. The skeletal structures were prepared from fresh fish. The specimens were boiled in fresh water and the skeletal structures were taken. Then the skeletal parts were kept in 5% KOH solution for about 48 hours to loosen the remaining muscles. Vertebrae of twelve specimens measuring 235, 304, 318, 332, 380, 423, 485, 485, 515, 515, 532, and 568 mm were taken. Palatine, cleithrum and opercular bones were taken from the fishes measuring 423, 485, 485, 515, 532, and 568 mm.

The vertebral column consists of 25 vertebrae. They are amphicoelous in nature. All the vertebrae including atlas show concentric thicker rings on the inner side of the centra. The prehaemal and caudal vertebrae show clear-cut white transparent zones alternating with equal distance. In the present study the specimens 235, 380, 485, 532 and 568 mm show 1-5 rings respectively (Fig. 1). Similarly other skeletal structures like palatine, cleithrum and operculum also show the markings on their surfaces. More data are being collected to substantiate these findings.

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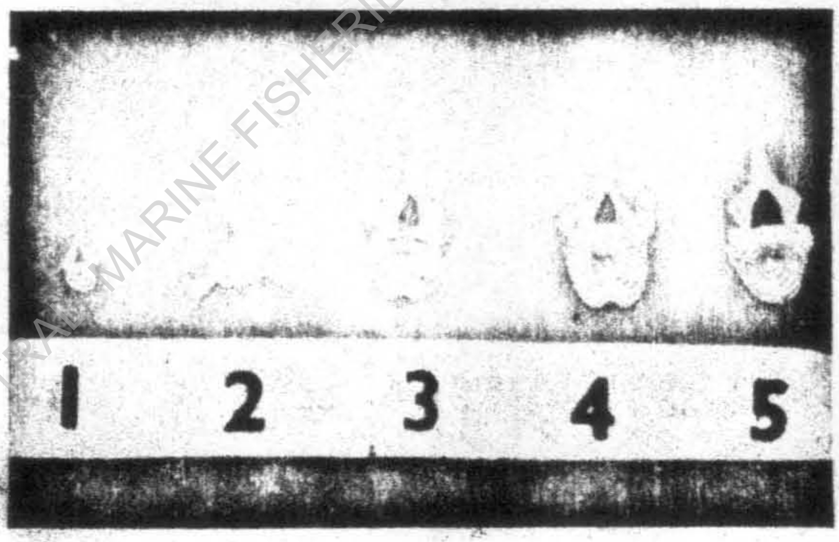

FIG. 1. Vertebrae of *Pomadasys hasta* (Bloch). 1. Length 253 mm showing 1 ring. 2. Length 380 mm showing 2 rings. 3. Length 485 mm showing 3 rings. 4. Length 532 mm showing 4 rings. 5. Length 568 mm showing 5 rings.

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Mortality of Fishes due to Oil Tanker Disaster in Gujarat Coast

On 18th June, 1973 the Oil Tanker M.T. "COSMOS PIONEER" broke into two pieces releasing 18,000 tons of light diesel oil near Porbandar of Gujarat Coast, when its weather was stormy due to the South West Monsoon. The sudden mishap took place when the tanker was on its way from Bombay to Kandla. Streaks of oil spread out from the tanker affected the entire marine ecosystem of that area. Within 48 hours of mishap 220 km. of Porbandar coast was polluted by oil and eventually over 600 km. of coast on 7th and 8th day[1]. The oil pollution caused considerable damage to the pelagic fisheries especially clupeoids. Fresh fish samples were collected by second author from different centres around Porbandar and Dwarka for identification. The identification of fishes and further analysis were done by the first author. The majority of fishes were unhealthy with abnormal guts and exhibited smell of oil.

The floating dead fishes were mainly composed of *Nematalosa* sp., *Coilia* sp., *Thrissocles* sp., and *Chirocentrus* sp., which constitute 50% of the total dead fishes floating in that area. The mortality of fishes was estimated on the basis of visual observation and only representative samples were collected by the second author on board the vessel. Due to shortage of space and time the floating dead fishes could not be scooped and weighed with the fear which could contaminate the other edible fishes on board. The mortality of other floating dead fishes varied in percentage, hence it could not be estimated owing to the above said reason.

Species-wise mortality of fishes

Nematalosa nasus (Bloch) **, *Kowala coval* (Cuvier), *Coilia dussumieri* (Cuv. and Val.) **, *Setipinna taty* (Val.), *Thrissocles purava* (Ham.)**, *Chirocentrus dorab* (Forskal) **, *Harpodon nehereus* (Ham.), *Plotosus canius* (Ham.), *Anguilla bengalensis* (Grey & Hardw), *Muraenesox cinereus* (Forskal.), *Mugil cephalus* (Linn.), *Mugil parsia* (Ham), *Polynemus indicus* (Shaw), *Leiognathus blochii* (Val.), *Johnius coitor* (Ham.),

** 50% mortality

Otolithus maculatus (Cuv.), *Cynoglossus cynoglossus* (Ham.), *Cynoglossus lingua* (Ham.), *Mastacembelus armatus* (Lac.), *Scoliodon sorrokowah* (Cuv.).

The following could not be identified upto the species level as they were completely soaked and deteriorated in oil.

Trichiurus sp., *Lybia* sp., *Thrissocles* sp., *Kowala* sp., *Nematalosa* sp., *Ammodytes* sp., *Pleuronectes* sp., *Leiognathus* sp., *Otolithus* sp., *Metapenaeus* sp.

In conclusion it should be emphasised that the above study records only some of the more obvious and immediate effects on fishes. The effects of continuing pollution on eggs and larvae of pelagic and demersal fishes cannot be assessed at present. In addition to short term effects noted in the present study it may contribute to long term environmental degradation and the affected polluted areas may also take a conderable time to recover as happened during Torrey Canyon disaster in Cornish coast[2].

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A NOTE ON HYPEROSTOSIS IN THE PERCH *POMADASYS HASTA* (BLOCH)

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ABSTRACT

A case of hyperostosis in the skull bones of the perch, *Pomadasys hasta*, is reported. The oval-shaped protuberance of frontal and supraoccipital bones of the skull and also a small depression between the eyes are very prominent. This gives to the skull a hump-like appearance.

During the course of biological investigations on *Pomadasys hasta* at Bombay, the swollen nature of some skull bones, popularly called "stones" was noticed in two male specimens measuring 525 mm and 535 mm. The first specimen was collected from Crawford Market on 15-3-73 and the second, from Sassoon Dock on 13-11-73. The incidence of occurrence of such abnormal specimens were, however, very limited since only two such specimens were noticed out of a total of 3422 examined during the course of study. Both the affected fishes were probably four-year-olds, as was revealed by the otoliths.

In the normal skull, the supraoccipital is situated medially behind the frontal to which it is articulated anteriorly. In the abnormal skull, excessive thickening of the frontal and supraoccipital form two heavy bony masses. The semicircular curvature of the bones of the frontal region becomes swollen more antero-posteriorly than those of the supraoccptal region. The frontal ridges coalesce together forming a frontal crest posteriorly which remains unossified leaving a gap between the two ossified bones, resulting in slight concavity in the nape which is perceptible externally. The enlargement of supraocciptal takes place anterodorsally, the posterior part remaining as a thin transparent blade.

Investigation by earlier workers have drawn much attention to this phenomenon of hyperostosis in fishes and various explanations were given for their formation. Johnstone (1924) in his study of malignant tumours of fishes noted that some parasites can induce the disease — cancer. Ebina (1936) as cited by James (1960) stated extraordinary bone formation in the supraoccipital bone of *Evynnis cardinalis*. Barnard (1948) referred to this condition in *Chrysoblephus gibbiceps* and *Caranx equala* and termed it as hyperostosis. Gopinath (1951) attributed the extraordinary development and secondary ossification of supraoccipital crest in *Caranx sexfasciatus* and *Alectis indica* to a demand for hydrostatic balance and stability. James (1960) stated that in *Trichiurus lepturus* Linnaeus, the enlargement of various bones may either be a peculiarity of the species or could be a disease. Bhatt and Murti (1960) have revealed this condition in *Trichiurus haumela* (Forskal) as a case of Osteoma—

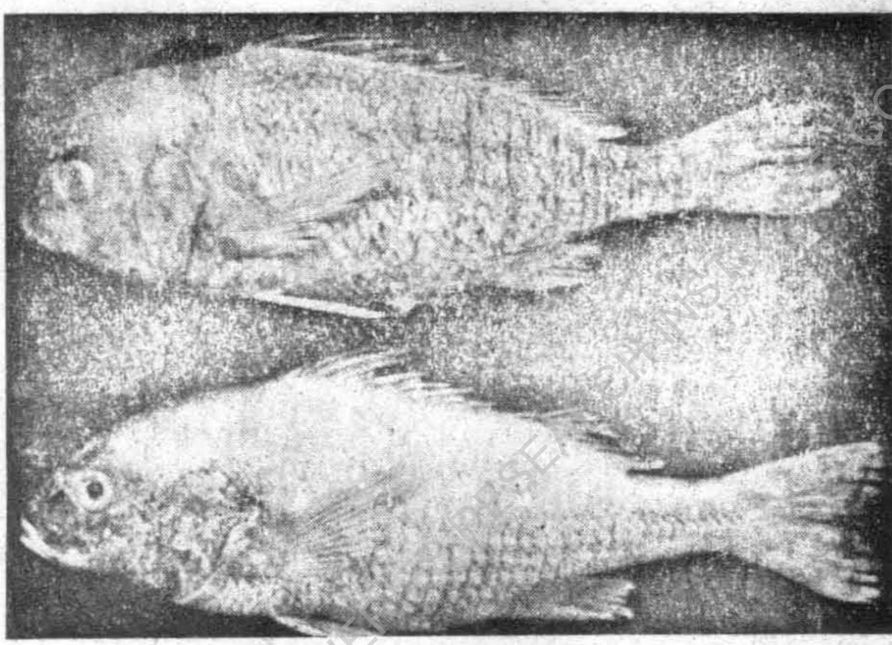

FIG. 1. *Pomadasys hasta* (Bloch), a specimen with hyperostosis (above) with a normal one (below).

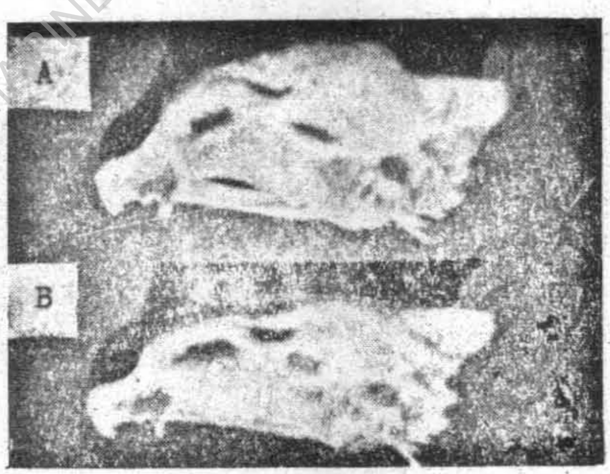

FIG. 2. The skull with hyperostosis of *P. hasta* (A) with that of normal one (B).

a neoplastic disease. Murty (1967) observed this phenomenon in *Drepane punctata* (Linnaeus). Experiments on Rainbow Trout, *Salmo gairdneri*, by Aulstad and Kittelsen (1971) proved that the abnormal body curvatures are partly heritable.

So far no satisfactory explanation has been given as to the exact nature of these bony outgrowths in fishes. However, it is assumed from the present study that the causative factor leading to this peculiar formation of the bones of the skull in *Pomadasys hasta* (Bloch) may be attributed to an inherited disease. Furthermore, this phenomena is very rarely met within this species.

I am grateful to Dr B. Krishnamoorthy, for critically going through the manuscript for its improvement. My thanks are due to Shri K. Prabhakaran Nair for the photograph.

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Instances of caudal fin deformity in some Fishes of Bombay waters*

While observing the trawl and dol (Bag net) net fish landings at Sassoon Docks and Versova, some interesting instances of caudal deformities of five species of telosts : *Otolithus brunneus* Day, *Otolithus argenteus* Cuvier, *Drepane punctata* (Linnaeus), *Coilia dussumieri* (Cuv. & Val.) and *Trichiurus lepturus* Linnaeus were met with (Plate 1). The localities from where they were collected and the dates of their occurrence are presented in table 1.

Instances of deformities are rather uncommon. Deformity might involve both internal and external organs. Dawson[1] gave a valuable bibliography on anomalies of fishes. Reported instances of deformities in Indian fishes are quite limited[2-6]. The deformities are presumed to be the result of injuries caused by accidents or attack of predators on the young or adult fishes.

The nature of caudal deformity of the five species listed in Table 1 is described

TABLE 1.

Date	Locality (*Bombay*)	Species
25- 7-1973	Sassoon Docks	*Otolithus brunneus* Day
12- 2-1975	Versova	*Otolithus argenteus* Cuvier
27- 9-1974	Sassoon Docks	*Drepane punctata* (Linnaeus)
12-12-1974	Sassoon Docks	*Coilia dussumieri* (Cuv. & Val.)
13-12-1974	Versova	*Trichiurus lepturus* Linnaeus

here. Since the caudal fin was absent in all the fishes, the standard length which denotes the distance from snout to caudal peduncle was used for comparison with the normal ones.

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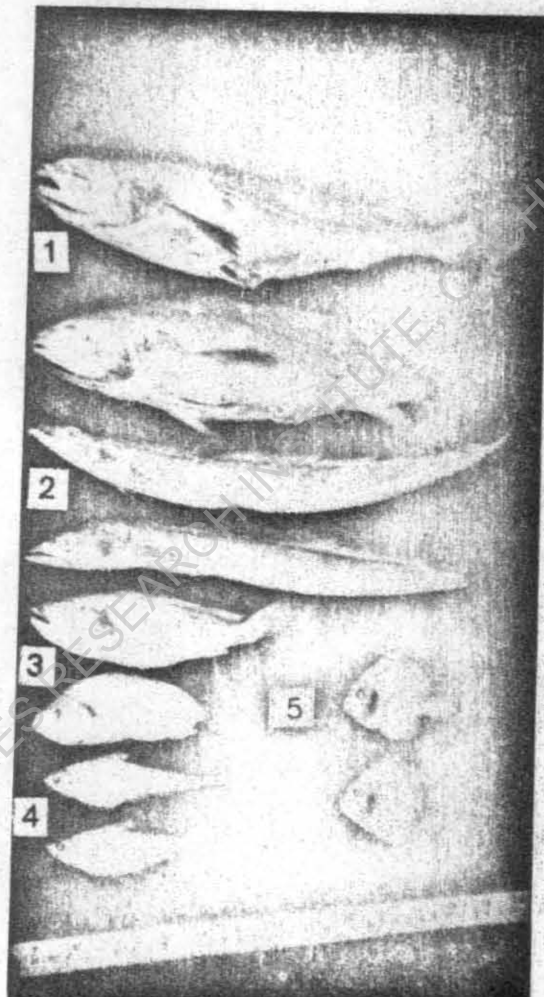

Plate 1. Normal and abnormal specimens.

1. *Otolithus brunneus* Day
3. *Otolithns agrenteus* Cuvier
5. *Drepane punctata* (Linnaeus)
4. *Coilia dussumieri* (Cuv. & Val.)
2. *Trichiurus lepturus* Linnaeus

In *Otolithus brunneus* the entire caudal fin was absent. The dorsal and anal fins were slightly longer than those of the normal ones. The growth at the tip of the caudal was seen to a certain extent and gradually retarded later. The caudal fin in *Otolithus argenteus* was completely absent and growth was entirely arrested in this re-

TABLE 2. **Morphometric characters of normal and abnormal specimens**

Characters	*O. brunneus* 25.7.73 Sassoon Docks		*D. punctata* 27.9.74 Sassoon Docks		*C. dussumieri* 12.12.74 Sassoon Docks		*T. lepturus* 13.12.74 Versova		*O. argenteus* 12.2.75 Versova	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1. Standard length	34.5 cm	26.5 cm	5.8 cm	5.8 cm	11.0 cm	8.2 cm	38.5 cm	29.5 cm	14.0 cm	10.3 cm
2. Head length	8.8 cm	8.5 cm	2.6 cm	2.5 cm	2.5 cm	2.6 cm	44.4 cm	45.7 cm	4.7 cm	4.3 cm
3. Depth of body	5.7 cm	6.2 cm	5.8 cm	5.9 cm	2.8 cm	2.6 cm	2.8 cm	2.8 cm	4.0 cm	3.7 cm
4. Snout length	1.8 cm	2.0 cm	1.0 cm	0.9 cm	0.5 cm	0.4 cm	2.5 cm	2.4 cm	1.6 cm	1.2 cm
5. Diameter of eye	1.3 cm	1.2 cm	0.8 cm	0.7 cm	0.5 cm	0.6 cm	1.1 cm	1.1 cm	1.1 cm	1.0 cm
6. Predorsal distance	8.2 cm	9.4 cm	4.3 cm	4.4 cm	3.9 cm	3.7 cm	4.7 cm	4.8 cm	5.8 cm	5.0 cm
7. Dorsal length	18.5 cm	17.2 cm	4.2 cm	4.5 cm	1.1 cm	1.0 cm	6.0 cm	5.8 cm	9.9 cm	7.2 cm
8. Pectoral length	7.8 cm	8.7 cm	2.4 cm	2.6 cm	2.3 cm	2.2 cm	6.0 cm	5.8 cm	4.7 cm	3.8 cm
9. Pelvic length	22.0 cm	22.5 cm	2.3 cm	2.2 cm	3.8 cm	4.0 cm	16.2 cm	13.8 cm	5.4 cm	4.8 cm
10. Anal length	19.0 cm	20.5 cm	4.2 cm	4.1 cm	5.3 cm	5.2 cm	16.0 cm	14.7 cm	10.0 cm	8.3 cm
11. Caudal length	6.0 cm	..	2.4 cm	..	4.8 cm	..	10.0 cm	..	4.5 cm	..
12. Height of the caudal peduncle	0.9 cm	0.2 cm	0.9 cm	0.2 cm	1.1 cm	1.2 cm	1.5 cm	1.2 cm	1.4 cm	1.3 cm
13. Weight	630 gm.	546 gm.	11 gm.	10 gm.	15 gm.	12 gm.	42 gm.	32 gm.	41 gm.	31 gm
14. Sex	Indeterminate		Indeterminate		Male	Female	Male	Female	Male	Male
15. Stages	—	—	—		6th	5th	3rd	3rd	2nd	2nd

gion. The deformed specimen resembled the normal one in all other respects. The dorsal, ventral and pectoral fins of *Drepane punctata* were much more elongated than those of the normal specimen. Moreover, the height of the caudal base was reduced due to extended growth of dorsal and pelvic fins in the deformed specimen. Hyperostosis seems to be the only case of abnormality of *D. punctata* reported earlier[7]. In *Coilia dussumieri*, regeneration of rudimentary fin rays as four clusters were developed at the tip of the deformed caudal and retarded later. Due to the absence of entire caudal fin in *Trichiurus lepturus*, no sign of regeneration of fin rays at the caudal base was observed.

Eventhough all the five species have completely lost their caudal fins, they did not suffer any retardation in the growth of other parts of their body and normal functioning was not apparently hampered. The vertebral columns of all the deformed specimens were examined and compared with those of the normal specimens to study the exact location of deformity. It was noticed that the loss of the entire caudal fin did not bring any change in the vertebral column like shortened, curved, or otherwise malformed. The lesser height of the caudal base in some of the deformed specimens might be due to deformity of the caudal fin.

Some important morphometric measurements of normal and abnormal specimens to ascertain the variation in growth are given in Table 2.

The causes of deformities in fishes are numerous and that no single factor is sufficient to explain it[8]. Ecological environments or hereditary and congenital factors may play a role in such cases[9,10]. However, in the present case, it has been presumed that the loss of the entire caudal fin of all the fishes may be due to mechanical injury or accident or attack of some predators or infection due to some parasites and this most probably could have occurred in the very early stages of development. But this has not been proved.

Sarkar and Kapoor[3] categorise the deformities in two groups : (1) absence of the caudal peduncle and the entire fin or portion of the fin, (2) the presence of the caudal peduncle and the fin. The fishes described in the present observation fall in the first category.

In general, fishes have little power to regenerate lost parts. In the present study, except in *C. dussumieri*, lack of regeneration of fin rays in all the rest of the fishes is noticed. Regeneration among Indian fishes is described by many earlier workers[11-14]. Generally the process of regeneration involves the regrowth of the fin rays to begin with and the other truncated components of the body. Further the number of fin rays regenerated depends upon the extent of the regenerating area also.

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Effects of varying salinities and body weight changes in an estuarine crab *Uca annulipes* (Milne-Edwards).*

Among the ecological factors governing the life of aquatic animals, the physical and chemical characteristics of the waters in which they live are the most important. Experiments designed to study the influence of these factors can provide information on the physiological machanisms and also on the tolerance range of each of these identifies[1].

In India, studies on systematics, biometrics, ecological and physiological aspects of *Uca annulipes* (Milne-Edwards) were done by some earlier workers[2-4]. The effects and body weight changes of the estuarine crab, *Uca annulipes* (Milne-Edwards) when introduced to different salinities from the natural medium were dealt with in the present study.

Four live crabs of the species *U. annulipes* were collected from the Vellar estuary of Porto Novo (C 11° 29′ N 79° 49′ E) on the east coast of India. The weight of all the four individual crabs were taken in the physical balance after removing the moisture completely with the help of filter paper. The specimens were placed in separate beakers containing 500 CC of 25%, 50%, 75% and 100% sea water. Tap water of 375 CC was mixed with 125 CC of sea water for the preparation of 25% and 50% and 125 CC of tap water was mixed with 375 CC of sea water for 75% sea water.

After two hours the specimens were removed from the sea water and the moisture was removed with the help of filter paper and their weight recorded. The difference in weight gives the weight gained or lost by the individual crabs.

It was seen from the result (Table 1) that the crabs in 25% and 50% sea water increased in weight and their percentages were 1.56% and 1.43% respectively. The osmotic pressure of the external medium was less hypertonic than the internal medium. The blood of the crab was hypertonic to the medium and there was inflow of water which caused the increase in weight. The salinity tolerance of the crabs depends on the osmotic regulation they are capable of.

The weight of the crabs decreased in 75% and 100% sea water and their percentages were 0.288% and 0.684% respectively. The range between 50%-75% may be isoosmotic to the blood. The difference in weight gives the weight gained or lost by the osmotic inflow or outflow of the water medium. Due to osmosis, internal medium goes out and external medium comes in with the result of decrease and increase in weight and volume. The present study revealed that body weight changes of *U. annulipes* was effected due to varying salinities.

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TABLE 1 : Body weight changes of *Uca annulipes* (Milne-Edwards) in different salinities.

Sea water	Initial Wt. in grams	Final Wt. in grams.	Difference	Percentage	
25%	2.56	2.60	0.04	1.56%	increase +
50%	2.9	2.13	0.4	1.43%	increase +
75%	3.125	3.116	0.009	0.288%	decrease —
100%	2.920	2.900	0.020	0.684%	decrease —

* This study formed as a part of the dissertation submitted in the partial fulfilment of the requirements for the M.Sc. degree from Annamalai University, 1967.

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A NOTE ON PARASITISED OVARIES IN THE PERCH *POMADASYS HASTA* (BLOCH)

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An instance of diseased ovaries in a specimen of *Pomadasys hasta* (Bloch) is reported. The fish measuring 535 mm total length was caught in the Hook & Line operation at Sassoon Dock on 9th November 1973. The specimen collected in fresh condition, was studied carefully.

In the specimen, externally, a thick cloud of dark patches on the lateral walls of the ovaries could be noticed, while internally it was found that the degenerated ova were accumulated in a separate sheath. In addition, a large number of nematode parasites were seen in both the lobes of the ovary (Fig. 1). The dark patches represent the degenerated and deteriorated ova which occurred

due to the infection by the nematode parasites. The worms were in dead condition and were in the vicinity of the dark patches. Moreover, the sheath containing the degenerated ova was continuous up to the posterior end of the ovary.

Raju (1960), and Thomas and Raju (1964) in their observation on *Katsuwonus pelamis* reported that the enormous development and hardening of the left lobe of the ovary with the complete destruction of the mature ova in it were probably due to extensive infection by larval nematode worms in large numbers. Annigeri (1962) observed that the parasitisation caused by the nematode, *Philometra* sp. in the ovaries of *Otolithus argenteus* had resulted in the atrophy of the major part of the ovaries. However, in the case of the Indian mackerel, *Rastrelliger kanagurta*, Antony Raja and Bande (1972) expressed that although the presence of young nematodes has not affected the ovaries in the manner reported by the earlier authors, it is possible that it would have contributed to the abnormal enlargement of the additional sac of the ovary. In the present investigation it was observed that the infection of ovaries in *P. hasta* was caused by the nematode *Contracaecum aduncum* Rudolfi and the case thus appears to be different from any of the above reports.

I am grateful to Dr. B. Krishnamoorthy for critically going through the manuscript and to Dr. B. T. Antony Raja for offering valuable suggestions for its improvement. My thanks are also due to Miss V. P. Kotwal, Institute of Science, Bombay for identifying the parasite.

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MISCELLANEOUS NOTE

33 DESCRIPTION OF ISOPOD *CIROLANA PARVA* HANSEN PARASITIC ON THE EYE BALLS OF DOLPHIN, *DELPHINUS DELPHIS* LINNAEUS WITH A KEY TO THE INDIAN SPECIES OF THE GENUS *CIROLANA* LEACH

(*With eleven text-figures*)

INTRODUCTION

Stebbing (1905) recorded *Cirolana parva* from Ceylon waters and Chilton (1924) reported it from Chilka lake, India. As there is no illustration to assist identification of *C. parva* in the earlier accounts of Stebbing (1905) and Chilton (1924) we have described the species with full illustrations in this paper. Seventeen specimens of *Cirolana parva* Hansen have been collected from the eye balls of the dolphin *Delphinus delphis* Linnaeus caught from Palk Bay, Mandapam on 30-xi-1971. The species of the genus *Cirolana* so far recorded from Indian region are *Cirolana willeyi*, *C. bovina*, *C. parva*, *C. venusticauda*, *C. sulcaticauda*, *C. pleonastica*, *C. fluviatilis*. *C. pustulosa* and *C. sulcata*. A synoptic key to the identification of these species is also given.

Distinguished by the presence of five free pleonal segments with a pleotelson. Endopods of pleopods 1 to 4 fringed with setae. Eyes absent or present. Peduncle of the second antennae five jointed. Molar process blade like with fine sharp and closely arranged teeth. Mandibles with lacinia mobilis; peraeopods ambulatory. Telson broad, sub-triangular; setae on the margin of the pleotelson and uropod are elongated with fine bristles. Maxillipeds with hooks on second segment.

Cirolana parva Hansen (Figs. 1-11)

1890, *Cirolana parva* Hansen, *Vid. Selsk. Skr., Ser.* 6, 3, pp. 321, 340, pl. 2, fig. 6-6b, pl. 3, fig. 1-1d.

1902, *Cirolana parva* Moore, *Bull. U. S. Fish. Com.*, 20, pt. 2, pp. 166-167, pl. 8, figs. 6-8.

1905, *Cirolana parva* Hansen, Stebbing, *Ceylon Pearl Oyst. Fish. Rep.*, part IV, No. 23, p. 12.

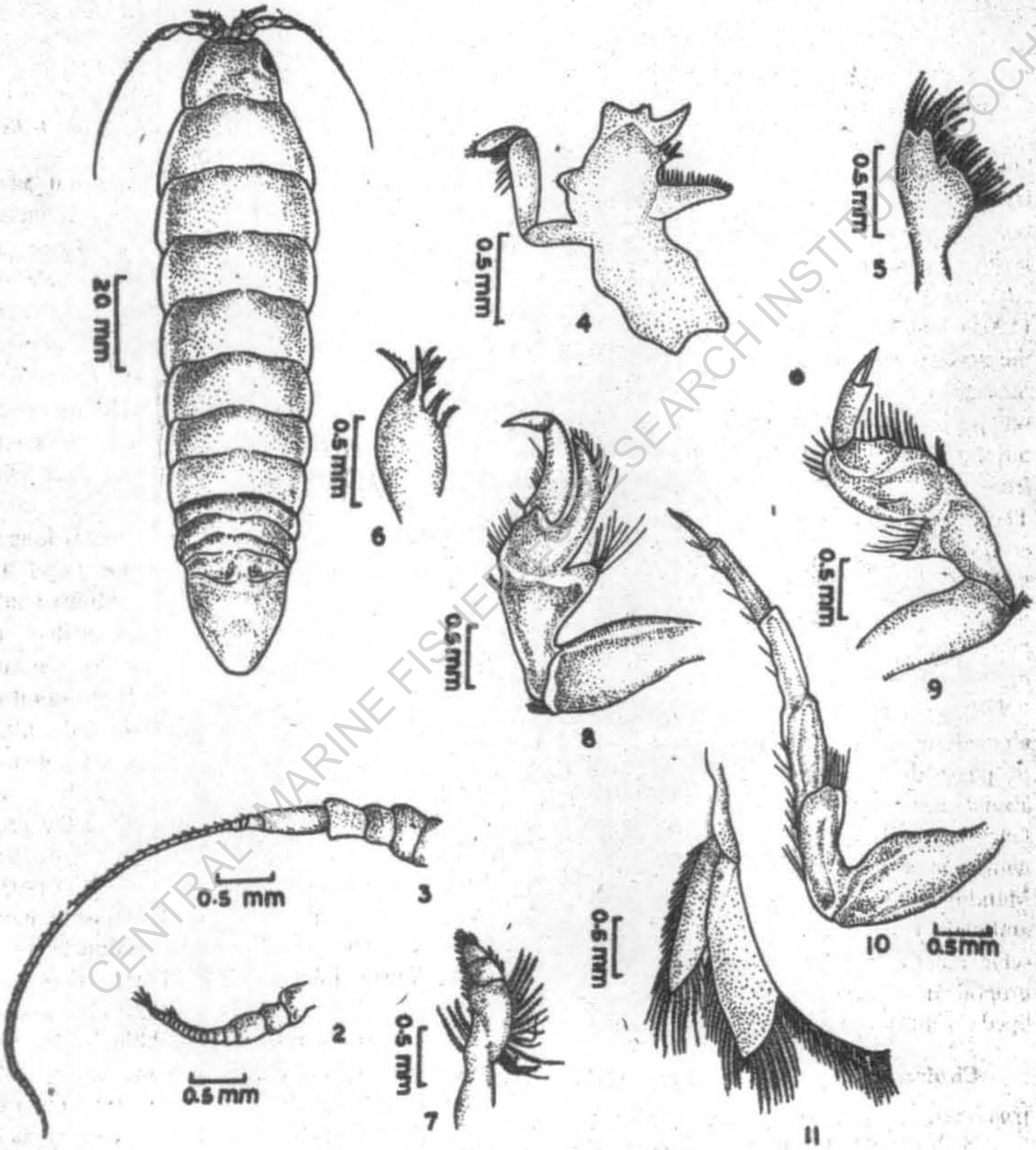
1924, *Cirolana parva* Hansen, Chilton, *Mem. Indian Mus.*, 5(12), pp. 883-884.

Body smooth, telson broad, sub-triangular in shape., apical margin of telson rounded with 6 thick short setules of which three on the right side and three on the left side of the telsonic segment, close to the apical margin. The terminal segment also bears numerous fine setae along the margin, the outer ramus of the uropod is shorter and narrower than the inner which is very much broader, uropod margins furnished with fine setae and a few setules.

The third joint of the first antenna is longer than the first and second joints, the flagellum is longer than the peduncle and fifteen-jointed. Hansen (1890) described the flagellum as eleven-jointed, much shorter than the peduncle, Moore (1902) as eleven-to twelve-jointed and Stebbing (1905) as nine-jointed, little shorter than the peduncle. The second antenna about more than thrice as long as the first, last joint of the peduncle longer than the preceding, flagellum much longer than the peduncle about fortyone-jointed. Stebbing (1905) has described that the second antennae have the first three joints of the peduncle very short, fourth joint a little shorter than the fifth and flagellum 22-26 jointed. The second antennae closely resembled stebbing's description except in the flagellum being more jointed. The joints of the flagellum of the antennae were more numerous in the specimens described by Chilton (1924). The antipenultimate joint of the maxilliped possess three elongated setae on the outer margin. The maxilliped joints setose along their margin. The third palp of the outer margin of the maxilliped furnished with sixteen elongated setae and the setae are ornamented with fine bristles.

Maxilla I and II: First maxilla composed of two lobes—a sensory endopod and a biting exopod., there are long setae present on the two lobes. The second maxilla also possess long setae which serves as food strainers.

Mandibles: Mandibles are strong and serve as biting structures., the incisor process or the cutting part is thickly chitinised., the mandibles have a sensory palp of three articles—lacinia mobilis, molar teeth and mandibular palp. The mandibular palp is curved at the apex and the molar teeth is blade—like which is characteristic of the genus *Cirolana*.



Figs. 1-11. ***Cirolana parva*** **Hansen. 1. Dorsal view of the entire specimen; 2. First antenna; 3. Second antenna; 4. Mandible; 5. Maxilla I; 6. Maxilla II; 7. Maxilliped; 8. Peraeopod I; 9. Peraeopod II; 10. Peraeopod VII; 11. Telson and Uropod.**

Size: The length and breadth of males ranged between 8.0 and 17.0 mm and 1.0 and 4.2 mm .espectively. The length of females ranged between 8.5 and 17.0 mm and the breadth between 1.5 and 3.0 mm.

General Distribution: Gulf of Mexico, West Indies, Tale Sap, Sri Lanka and Chilka Lake.

Remarks: *Cirolana parva* has been reported for the first time from the Palk Bay region. Though Stebbing (1905) and Chilton (1924) have described *C. parva*, this report gives detailed description and illustration of the species.

KEY TO THE INDIAN SPECIES OF THE ISOPOD GENUS *Cirolana* LEACH 1818.

1. Frontal lamina pentagonal or hexagonal in shape, margin of cephalon medially produced., posterior margin of the peraeon segments and the pleon armed with spines., dorsal surface of telson without spines. .. .. *C. willeyi*
2. Frontal lamina is differently shaped in adult males., posterior peraeon segments not with distinct spines but with crenulate margin., pleon segments armed with spines, telson conical with a pair of large submedian spines. *C. bovina*
3. Frontal margin of sephalon slightly produced., peraeonal segment VII as broad as other peraeonal segments., eyes small not on border of cephalon., endopod of uropod reaching beyond the posterior margin of pleotelson. *C. parva*
4. Frontal lamina quadrangular in shape., margin of cephalon medially produced. .. .. *C. venusticauda*
5. Margin of cephalon slightly produced., transverse rows of spines along the posterior margin of the peraeon segments., telson with double row of tubercles or spines. .. *C. sulcaticauda*
6. Frontal margin of cephalon smooth, angular., frontal lamina narrow pentagonal, very broad at base., posterior margin of the posterior peraeon segments with one to three transverse rows of spines., pleon tuburculate., telson with a series of pairs of tubercles. .. .. *C. pleonastica*
7. Frontal margin of cephalon rounded., posterior peraeon segments and the pleon armed with spines., dorsal surface of the telson with two submedian spines followed by two parallel rows of three to four small spines. *C. fluviatilis*
8. Frontal margin of cephalon rounded., posterior margin of the peraeon segments with a single row of spines., telson with double row of elongated tubercles. .. .. *C. pustulosa*
9. Frontal lamina widening to middle., one to three transverse rows of spines along the posterior margin of the peraeon segments., pleon not tuberculate., telson grooved with a series of pairs of tubercles or spines .. *C. sulcata*

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September 3, 1977.

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AN INSTANCE OF REGENERATED SCALE IN THE PERCH *POMADASYS HASTA* (BLOCH) (POMADASYIDAE).—An unusual type of scale which is wider and of different shape compared to normal one was noticed behind the pectoral fin of the specimen of *Pomadasys hasta* (Bloch). The fish measuring 480 mm in total length was caught in a gill net operation at Sassoon Dock, Bombay on October 10, 1973. The scale was a ctenoid one. Three growth rings were seen in the scale. Description of the structure and nature of the unusual scale are given in this note. Among 888 specimens observed during 1970–73 only one such scale was noticed in a specimen behind the pectoral fin on the right side.

The unusual scale measured 19 mm in height and 30 mm in width. The height is slightly more than that of a normal scale (18 mm) while the width is much more than that of normal one (19 mm). The height of the scale is slightly more in the lower portion compared to the upper portion giving the appearance of two scales fusing into one. However, it is not an instance of fusion of two scales since there is no evidence for the same like a distinct line or ridge in between the two portions. The focus of the scale is broad and expanded unlike in normal scale (Fig. 1). The expanded central portion of the scale is devoid of circuli. Three growth rings are present in the scale. Fifteen radii are found in the scale in contrast to ten in normal one.

Scales of teleostean fishes develop first in primary papillae and later in secondary papillae when they are formed. Irregularities in the scales occur in some individual fishes and reported by Huntsman (1918).

A case of an atypical scale with two foci both in the middle zone of the scale was described in *Sciaena coitor* (Hamilton) by Mookherjee (1948). According to Baragi and James (1976) in the scale of *Johnieops osseus* (Day) there is a single focus located on one side of the scale very close to the ctenii, the radii are bent instead of being

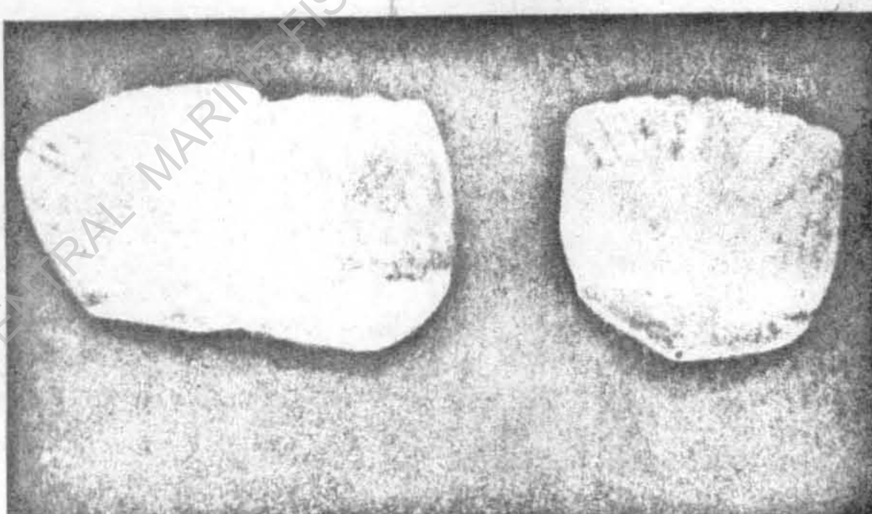

Fig. 1. An instance of regenerated scale in the perch *Pomadasys hasta*.

straight and a blank space typical of a regenerated scale is present. In the present observation the irregular scale of *P. hasta* reported here might have developed as a result of two scale papillae growing together and giving rise to it, or it may be a regenerated scale. The former may not be the reason and according to Rounsefell and Everhart (1953) as a scale developing from two papillae has two foci. The expanded focus of the unusual scale without circuli and the irregular shape of the scale suggest that it is a regenerated one.

I am grateful to (late) Dr. K. V. Sekharan, Central Marine Fisheries Research Institute for giving valuable suggestions and to Dr. K. Satyanarayana Rao of the same Institute for critically going through the note.

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SUITABILITY OF BRACKISHWATER AREA OF RIVER COOUM AT CHEPAUK, MADRAS FOR AQUACULTURE

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ABSTRACT

The present paper deals with the survival rate and adaptability of cultivable mullets and mussels to polluted waters; elucidates the the toxicity of River Cooum Estuary its suitability for aquaculture and explores the possibilities of utilising the sewage wastes for fishery resource.

To find out the survival rate and adaptability of mullets of the species Mugil cephalus Linnaeus, Liza dussumieri (Valenciennes) and Liza macrolepis (Smith) a wooden floating fish pen of the size 4x3x1½ m made of country wooden planks, covered on all the sides with nylon net (2 mm mesh size) leaving the top side open for the release of fry and fingerlings, was designed and commissioned at a distance of about 500 metres from the mouth of the River Cooum (near Marina Boat Club). For culturing the common Green Mussel Perna viridis Linnaeus a raft (1.5x1.5 m) made of bamboo poles with coir ropes tied at four corners of the raft was used.

Altogether five sets of culture experiments on mullet fry and fingerlings of the size 35-125 mm (wt. 2 gm -20 gm) were conducted during January-May 1979 in different periods of tidal amplitude. The survival rate of the mullet fingerlings in the first 24 hr. period was high (75%) when the fingerlings were released during high tide period which might be due to proper mixing of the oxygen rich sea water with river water. The survival rate gradually decreased when the mullet fingerlings were released at the time of low tide when there was complete depletion of dissolved oxygen due to the sewage mixed inland river water.

A total number of 800 mussel spats in sets of 200 each were transplanted and allowed to attach themselves to coir ropes hung from the corners of the raft. All the 800 spats were alive for 20 days and their survival rate was high (90%). Thereafter 50% of the experimental animals died. It is inferred that the mortality was

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probably due to closure of the mouth resulting in a total reduction in the dissolved oxygen.

An attempt was made to relate the survival rate of the experimental animals with the hydrological conditions of the water at the time of experimentation. In the light of the results obtained, the suitability of the River Cooum for further aquacultural practices is discussed.

INTRODUCTION

It has been predicted that by the turn of this century the population of India may be well over 1200 million people. In order to satisfy human values in terms of food production, aquaculture practices have been currently employed to augment the food resources(Jones, 1970). In India, with a coastline of 6500 km, the potential for developing aquaculture is very high(Silas et. al, 1976). In the marine biome, coastal impoundments have been used extensively for aquacultural practices. Reports of Central Marine Fisheries Research Institute summarise the results of preliminary experiments in coastal aquaculture using sea culture of fishes and prawns(CMFRI Newsletter 1977 and Venkataraman et. al, 1979). Further raft culture of Green mussel _Perna viridis_ Linnaeus off the open sea has been carried out by the Central Marine Fisheries Research Institute (CMFRI Report 1977). Sundararajan and Sampath(1975) carried out some experiments in the brackishwater habitat of Kovelong River with reference to cage culture of prawns. It has been reported that the river mouth estuary of Athankarai in Mandapam area may be suited for aquaculture with special reference to oyster culture during premonsoon period(Unpublished results). However, attempts to adapt a river mouth estuary which is highly polluted but offering conditions favourable for culture of commercially important fishes and mussels for aquaculture practices seems to be rare.

River Cooum under normal conditions maintains free connection with open sea during the post monsoon period. However, due to managerial attempts by the Government of Tamil Nadu, the river mouth has been kept open almost all round the year. In spite of such attempts the river continues to be in a highly polluted condition with the characteristic hydrological feature of oxygen deficit and multiplicity of faecal colliform and _Escherichia coli_(unpublished results). Under these circumstances it was thought worthwhile to carry out a few exploratory experiments using eurythermal and euryhaline organisms. For this purpose fishes like mullets _Mugil cephalus_ Linnaeus, _Liza dussumieri_(Valenciennes) and _Liza macrolepis_(Smith)which spend part of their life history in the estuaries and the mussel(_Perna viridis_ Linnaeus)which has enormous capacity to survive in a medium containing low dissolved oxygen were chosen as experimental animals. This paper summarises the results of the exploratory experiments, provides suggestions and recommendations for adopting the river estuarine system for aquaculture practices.

MATERIAL AND METHODS

Choice of the experimental site:

Based on the results of the earlier study, it has been found that the area adjacent to the free connection of the river with the sea may be more suitable for aquacultural experiments since the system is not subjected to serious stress due to Oxygen deficit. Therefore, construction of pen and location of rafts were made about 500 meters from the river mouth.

Fabrication of the pen and rafts:

Details regarding the construction of pen for fish culture have already been given in a earlier publication(Venkataraman et al., 1979). It may be mentioned that a wooden floating fish pen of the size 4x3x1½ mt made of country wood planks covered with all sides with nylon net with 2 mm mesh size leaving the top side open for the release of fish fingerlings were found suitable for the present purpose(Fig.1-a). The four corners of the floating pen were supported by casuarina poles erected from the river bed. After commissioning the experimental set up, the net was lifted periodically and cleared off the adhering debris in order to facilitate free flow of water. Periodic checks for predatory entrance through holesin the net were also carried out.

Bamboo rafts of 2½x2½ mt diamension were fabricated with a floating device and anchored secure by piling a casuarina pole. The rafts were held in position using fastening ropes(Fig.1-b).

Choice of the Specimens

Fingerlings of the species Mugil cephalus, Linnaeus Liza dussumieri (Valenciennes)and Liza macrolepis(Smith)were collected from Adyar estuary using a drag net. They were transported quickly in aquarium tanks to the experimental site. Length and weight measurements were made for the random samples. A known number of fingerlings were released carefully in the pen. The details regarding the hydrological factors such as salinity, temperature, oxygen pH and phase of the tide were noted.

Mussel spat of the species Perna viridis Linnaeus were collected from the Kovelong rocky coasts and they were left in batches in four ropes in sets of 200 spats in each group. The experimental animals are kept under constant observation and the percentage of mortality was assessed on a hours/daily basis over a period of 15-30 days.

OBSERVATIONS AND RESULTS

Experiment No.1

The test was carried out during January 1979 and a total number of 78 mullet fingerlings of the species Mugil cephalus Linnaeus in the size range of 85-120 mm were released in the experimental pen at 100-00 hrs. on 27th January 1979 during the low tide. Continuous watch was kept to assess the~~mxix~~ survival rate of the fish. Table No.1 and Graph No.1-a illustrate the survival rate of the fish. It may be of interest to point out that the experiment lasted for a period of 24 hrs. during which time 50% mortality was seen to occur after a period of 8 hours. During the initial two hours the mortality rate was low, the percentage being 15.3%.

Table No.2 summarises the hydrological conditions that prevailed during the time of the experiment. It may be seen from the Table that the salinity ranged from 3.390% to 6.870% and the dissolved oxygen content varied from 1.122 to 4.470 ml/lit. There was no appreciable change in temperature and pH during the period. It is interesting to note that even though there was an enrichment of oxygen and an increase in the salinity of the medium during the high tide period, the survival rate remained very low.

Experiment No.2

The test was carried out during February '79 when 56 mullet fingerlings of the species Mugil cephalus Linnaeus in the size group of 95-140 mm were released inside the pen during high tide period, when the tidal amplitude was about 0.83 mt. The results of the surival rate are given in Table No.1 and illustrated in graph No.2. It is intere ting to note that 50% of mortality was seen to occur within 2 hrs. from the time of release and 100% mortality occurred after a period of 22 hrs recalling similar observations as reported in Experiment No.1.

It may be seen from Table No.1 that during the time of high tide, the increase in salinity was greater than the increase observed in experiment No.1, the value being 14.490% The amount of dissolved oxygen varied from 0.670 to 3.800 ml/lit. It is likely that death of the fish may be due to anoxic condition of the millieu and cyclic stress imposed by the fluctuations in dissolved oxygen content.

Experiment No.3

The third test was conducted during March 1979(1-3-79)when 35 numbers of mullet fingerlings of the speies *Liza dussumieri* (Valenciennes)between the length group of 110-140 mm were released during the low tide period. The results of the observations are recorded in Table No.1 and illustrated in Fig. graph No.10. It is interesting to note that mortality of *Liza dussumieri* registered a high value of 28% within half an hour of release and 100% mortality was registered within a period of one hour from the time of release.

It is interesting to note that the salinity value was higher during the low tide period, the value being 19.860 and the dissolved oxygen content varied within a narrow limit, The range being nil to 0.880 ml/lit. It is likely that specimens of *Liza dussumieri* may have low tolerant range for oxygen and consequently death may be due to anoxic conditions.

Experiment No.4

The test was conducted during April '79(15.4.79)when 82 number of mullet fingerlings of the species *Liza macrolepis*(Smith) between 35 and 120 mm length range were released during the high tide period. The results were recorded in Table No.1 It may be seen from the Table that 30% mortality was registered within 6 hours from the time of release and 100% mortality were seen to occur within a period of nine hours.

It may be seen from Table No.2 that during the time of the experiment the salinity of the medium ranged from 13.500 to 33.450 and the dissolved oxygen ranged from 0.780 to 4.910 ml/lit. The results point out that successive anoxic conditions prevailing during the low tide may be the primary cause for the high mortality

Experiment No.5

The experiment was carried out during the month of May 1979(19-5-79) A total number of 115 specimens of Liza macrolepis(Smith)were released during high tide period. The results are tabulated in Table No.1 and illustrated in graph No.5a. It is interesting to note that there is no mortality for a period of 3 hours since the start of the experiment xxx and there was a sudden high mortality of specimens on the 5th hour of the experiment, when the salinity and oxygen content registered a value of 18.43‰ and 0.45 ml/lit respectively. The 100% mortality was registered at 8 hr. from the start of the experiment recalling similar observations in the previous experiment.

Experiment No.6

The experiment was carried out during February 1979(15-2-79)when 800 spats of the green mussel, Perna viridis Linnaeus were allowed to settle on to coir ropes. The results are reported in Table No.1 It is interesting to note that the mortality of P.viridis was nil for a period of 20 days when the averagesalinity and dissolved oxygen content ranged from 8.26 to 21.23‰ 0.67 to 3.57 ml/lit respectively. There was 33% mortality of the mussels on the 21st day and the mortality rose to 88% on the 28th May and 100% mortality was registered on the 30th day. It may be pointed at this juncture that the mouth of the river was kept open during the entire period of the experiment(30 days). Another interesting point which may be mentioned in this context is that death of the mussels occurred first in the top layers and then in the lower runs of the rope.

Experiment No.7

The experiment was carried out during July 1979(18.7.79)when 600 nos. of mussel spats of Perna viridis Linnaeus were allowed to settle on to coir ropes. The results are reported in Table No.1 It is interesting to note that 74% of the mussel spats were dead at 48 hrs. and 98% at 72 hrs. At 96 hrs. there was 100% mortality. It may be pointed that unlike the previous experiment the pattern of mortality rate is of a higher order in that the mussels exhibited low rate of adaptability to the changing environmental condition. It may be seen from Table No.2 that salinity of the river water ranged from 8.40 to 16.80% whereas the Oxygen content was nearly nil during the low tide and shown a negligible increase during the high tide period, the value being 0.220 ml/lit. The high mortality may be due to continued closure of the mouth resulting in the low rate of oxygen replenishment during the high tide time.

DISCUSSION

In the River Cooum, pollution load due to the sewage contamination is very high(unpublished results). The results of the present study indicate the possible means by which pollution abatment may be achieved using aquacultural practices. The experiments dealing with mullets of the species Mugil cephalus Linnaeus, Liza dussumieri (Valenciennes)and Liza macrolepis(Smith)indicate that the River Cooum may not be suitable for the culture of fishes even on an experimental basis. The reason for unsuitability of the River may primarily be due to the Oxygen deficit as a consequence of heavy sewage pollution and its high degree of fluctuation even reaching upto nil values. The pollution load due to oxygen deficit is reduced by the incoming oxygen rich sea water during the high tide period. Since fishes in general are not adapted to withstand anoxic conditions for long periods of time they succumb easily to the pollution load during the low tide period. It is likely that if the river is flushed well and regularly the longivity of the fish may be extended.

Another aspect of interest that emerges out of the present study is that the different species of fishes may exhibit different levels of adaptation to withstand pollution load. For instance, Mugil cephalus Linnaeus appears to be relatively resistant to oxygen deficit in the aquatic environment than Liza dussumieri (Valenciennes) and Liza macrolepis (Smith). Further studies on different species of fishes may reveal which of the species of fishes is ideal for culture purposes under polluted conditions.

It is interesting to note that the results of the studies dealing with the green mussel, Perna viridis Linnaeus show that invertebrate species which have the mechanisms to resist unfavourable conditions by closing their shells tightly and with a power down metabolic activity may be suited for culture purpose in a river estuary like Cooum. Eventhough the external (environmental) medium is low in dissolved oxygen, the green mussel Perna viridis Linnaeus may tide over the oxygen deficit period by closing the shells tightly and enclosing some amount of water within the closed shells. In the present study, it has been noted that P. viridis housed in the middle section of the hanging rope culture set up live longer than the specimens of P. viridis located at the top few layers of the river water. It is known that the incoming high tide sea water rushes in the form of a wedge usually called the salinity wedge. This section of water, found in the middle portion of the river, carries with it a rich supply of oxygen. It is likely that species of P. viridis may feed verociously and respire due to the return of favourable condition ameliorated by the oxygen rich high tide sea water rich in particulated suspended matter. The present study reveals that the death of P. viridis is mainly due to the continued oxygen deficit as result of the closure of the river mouth by sand bar formation. By way of recommendation, it may be mentioned that if the River Cooum is to be made suitable for aquacultural practices in order to convert pollution into a resource then sand bar formation at the river mouth must be regularly prevented and the estuarine part of the river must be flushed throughly and continually by the incoming high tide waters.

Summary

1. A total number of seven culture experiments were performed using mullets of the species *Mugil cephalus* Linnaeus, *Liza dussumieri* (Valencinnes) and *Liza macrolepis* (Smith) and green mussel *Perna viridis* Linnaeus at the highly polluted estuarine region of the river Cooum.

2. It is found that specimens of *M. cephalus*, *L. dussumieri* and *L. macrolépis* succumb easily to the environmental pollution load than *P. viridis*. It is also indicates that among the fishes *M. cephalus* relatively tolerates anoxic conditions relatively better than *L. dussumieri* and *L. macrolepis*.

3. Specimens of *P. viridis* live longer in a polluted environment like the River Cooum estuary. Under normal conditions, they have been observed to live for a period of 30 days. Normally death of *P. viridis* resulted because of closure of the river mouth by sand bar formation leading to the reduction in the amount of dissolved oxygen content.

4. It is proposed that if River Cooum is to be made suitable for aquaculture practices and thereby to reduce pollution by biological means then the sand bar formation must be prevented and the river to be flushed regularly and continually.

Acknowledgements

We wish to acknowledge our thanks to the Chief Engineer (Irrigation), Public Works Department, Government of Tamil Nadu for according necessary permission to set up the pens for experimental culture purposes at the estuarine region of the River Cooum. One of us (P.N.) wish to thank Indian Council of Agricultural Research (ICAR) for the award of Senior Research Fellowship.

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TABLE NO.1

Mortality rate of the Test Animals in Hours / Days

Sl.No.of experiment	Date of experiment	Time of release	Name of the Test animals	Total number of speci- mens released	Time dura- tion in hours/ days	Phase & height of the tide (in metre)	No.of morta- lity	Per- cent- age mor- tality	Cumulative percent- age mortality
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	27-1-79	10 A.M.	*Mugil cephalus* Linnaeus	78	0 hrs.	High tide (0.85)	Nil	Nil	Nil
		12 A.M.			2	Low tide (0.09)	12	15.38	15.33
		13 P.M.			3	Low tide (0.03)	26	33.33	48.71
		19-P.M.			8	High tide (1.20)	7	8.97	57.68
		1 A.M.			15	Low tide (0.01)	10	12.82	70.50
		5 A.M.			19	High tide (0.009)	19	12.82	83.32
		8 A.M.			24	High tide (1.02)	13	16.66	99.98

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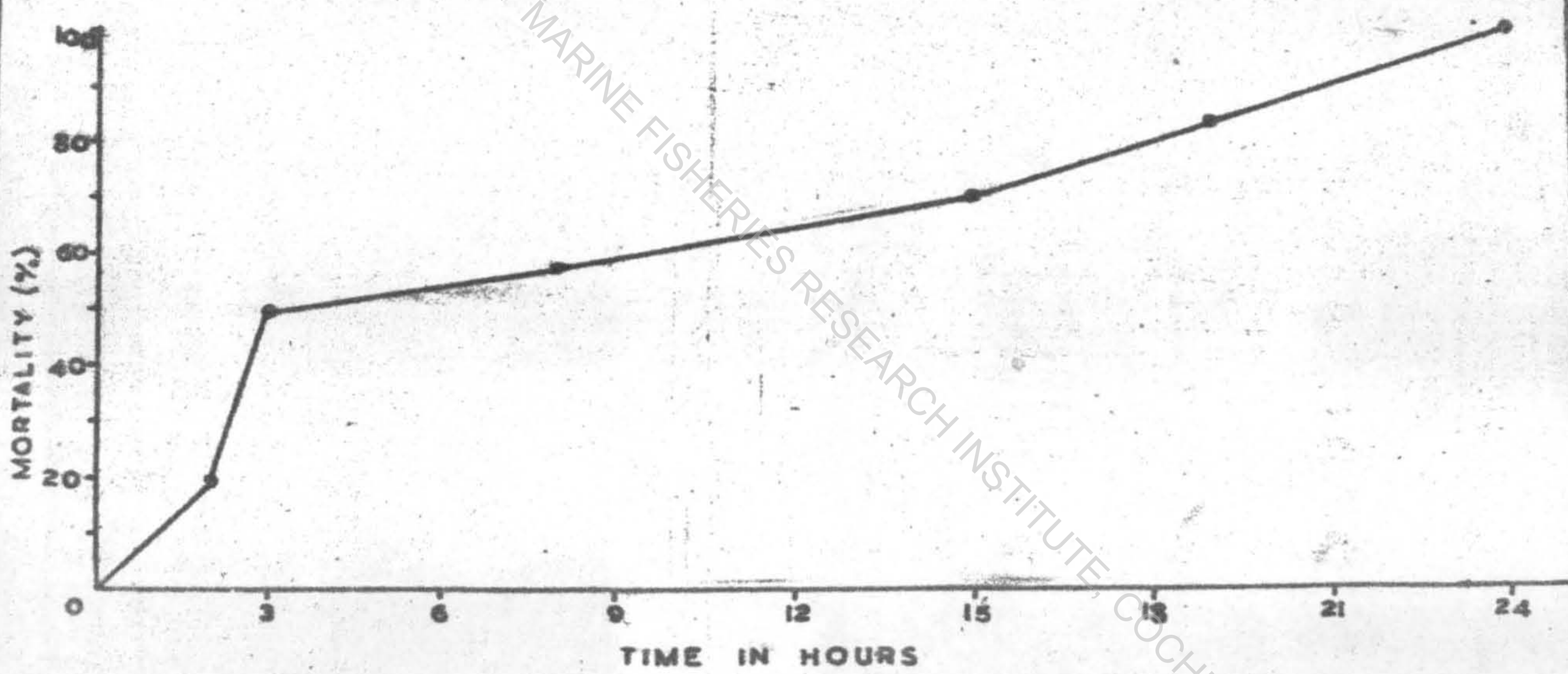
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2	15-2-79	8-00 A.M.	Mugil cephalus Linnaeus	56	0 hrs	High tide (0.83)	NIL	NIL	NIL
		11-00 A.M.			3 ,,	High tide (0.76)	33	58.92	58.92
		14-00 P.M.			6 ,,	Low tide (0.11)	3	5.35	64.27
		17-00 P.M.			9 ,,	Low tide (0.09)	3	5.35	69.62
		20-00 P.M.			12 ,,	High tide (1.02)	5	8.92	78.54
		1-00 A.M.			17 ,,	High tide (0.98)	5	8.92	87.46
		6-00 A.M.			22 ,,	Low tide (0.06)	7	12.50	99.96
3	1-3-79	9-00 A.M.	Liza dussumieri (Valenciennes)	35	0 ,,	High tide (1.02)	Nil	Nil	Nil
		9-30 A.M.			½ ,,	High tide (1.02)	10	28.57	28.57
		10-00 A.M.			1 ,,	High tide (1.03)	25	71.42	99.99
4	15-4-79	9-00 A.M.	Liza macrolepis (Smith)	82	0 ,,	High tide (1.19)	Nil	Nil	Nil
		12-00 A.M.			3 ,,	High tide (0.87)	18	21.95	21.95
		15-00 P.M.			6 ,,	Low tide (0.26)	9	10.97	32.92
		18-00 P.M.			9 ,,	Low tide (0.24)	55	67.07	99.99

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
5	19-5-79	13-00 P.M.	Liza macrolepis (Smith)	115	0 hrs.	High tide (0.94)	Nil	Nil	Nil
		16-00 P.M.			3 ,,	High tide (0.79)	Nil	Nil	Nil
		18-00 P.M.			5 ,,	Low tide (0.48)	75	65.21	65.21
		21-00 P.M.			6 ,,	Low tide (0.33)	20	17.39	82.60
		21-00 P.M.			8 ,,	Low tide (0.35)	20	17.39	99.99
6	15-2-79	17-00 P.M.	Perna viridis (Linnaeus)	800	0 ,,	Low tide (0.11)	Nil	Nil	Nil
	8-3-79	12-00 P.M.			21 ,,	Low tide (0.31)	264	33.00	33.00
	15-3-79	17-00 P.M.			27	High tide (0.88)	444	55.50	88.50
	16-3-79	17-00 P.M.			29	Low tide (0.29)	87	10.87	99.37
	17-3-79	17-00 P.M.			30	Low tide (0.20)	7	0.62	99.99
7	18-7-79	8-00 A.M.		600	0	Low tide (0.39)	Nil	Nil	Nil
	21-7-79	8-00 A.M.			48	High tide (0.97)	448	74.66	74.66
	22-7-79	8-00 A.M.			72	Low ~~High~~ tide (0.30)	142	23.66	98.32
	23-7-79	8-00 A.M.			96	High tide (1.04)	10	1.66	99.98

*Used in the construction of graphs.

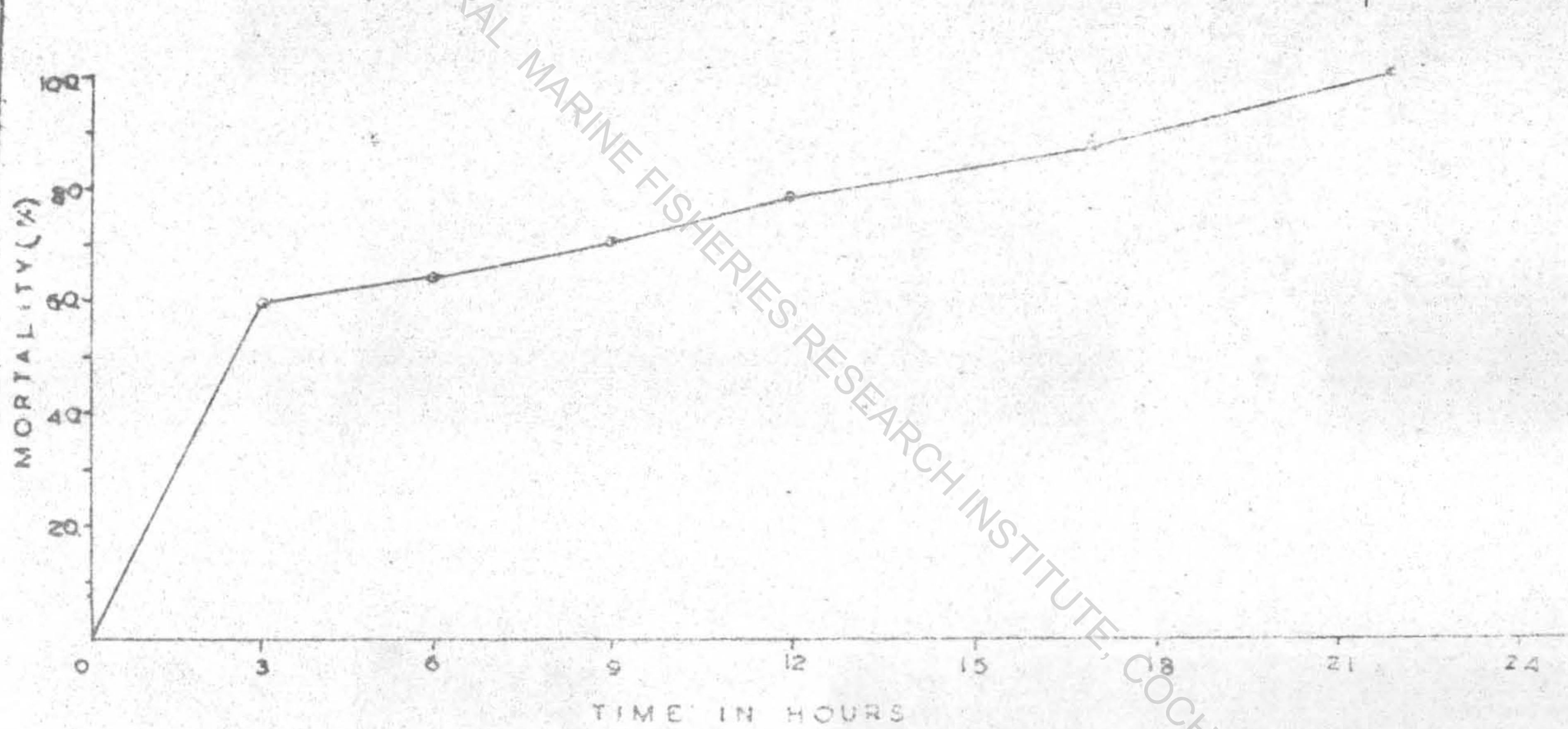
FIG.1. MORTALITY RATE OF *MUGIL CEPHALUS* LINNAEUS

DATE: 21-7-79



MORTALITY RATE OF *MUGIL CEPHALUS* LINNAEUS

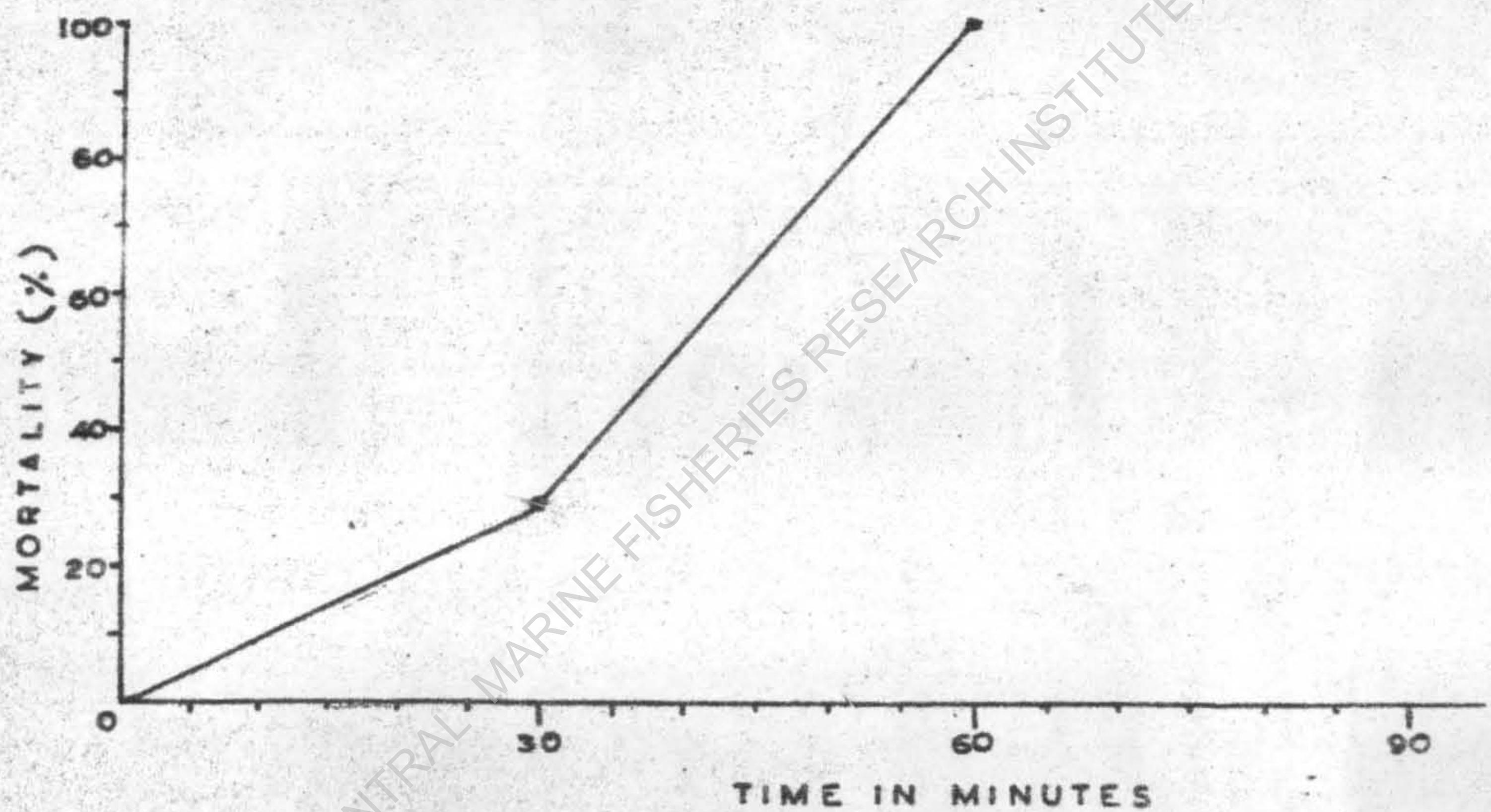
FIG. 2.



MORTALITY RATE OF LIZA DUSSUMIERI (VALENCIENNES)

FIG.3

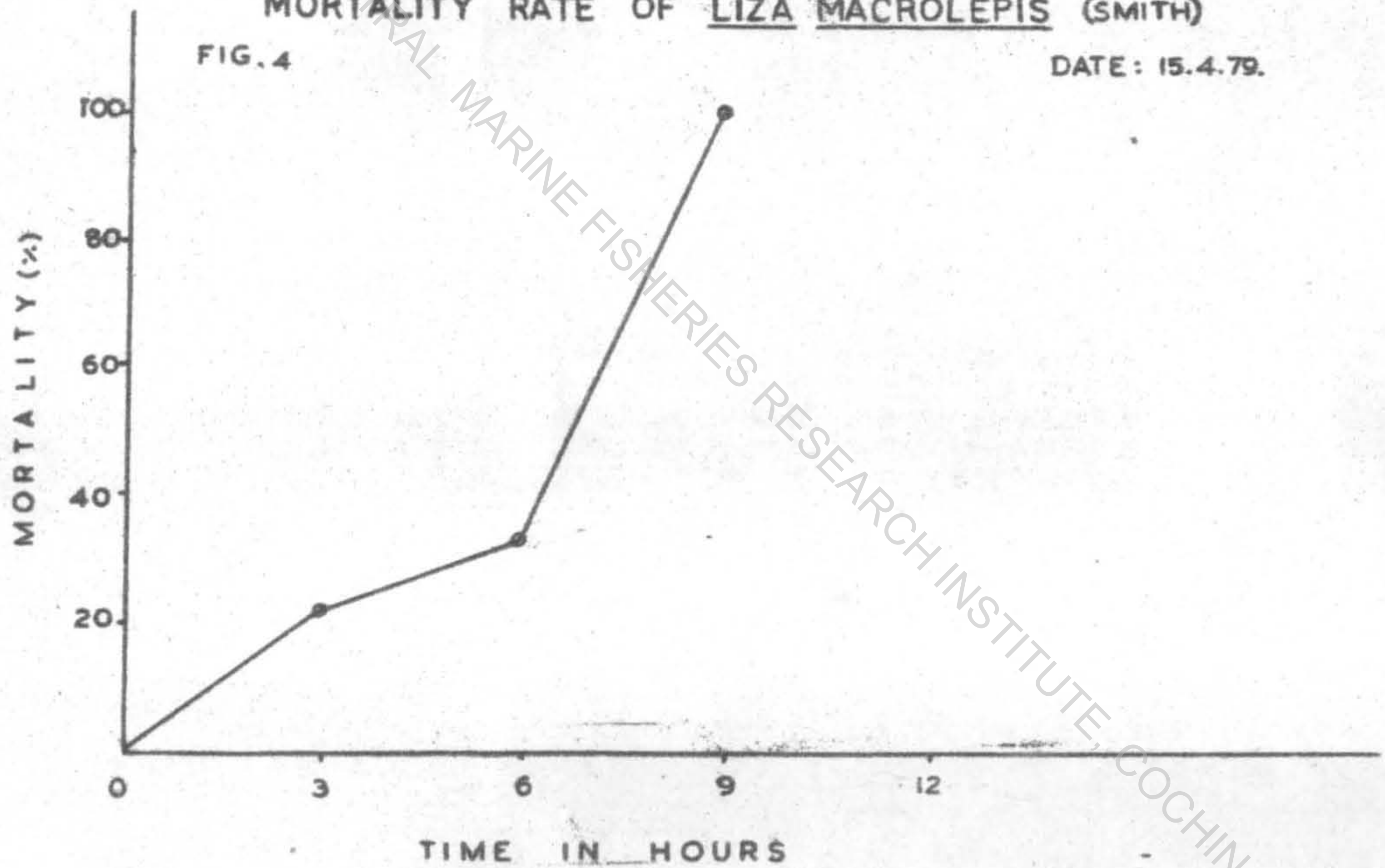
DATE: 1-3-79



MORTALITY RATE OF *LIZA MACROLEPIS* (SMITH)

FIG. 4

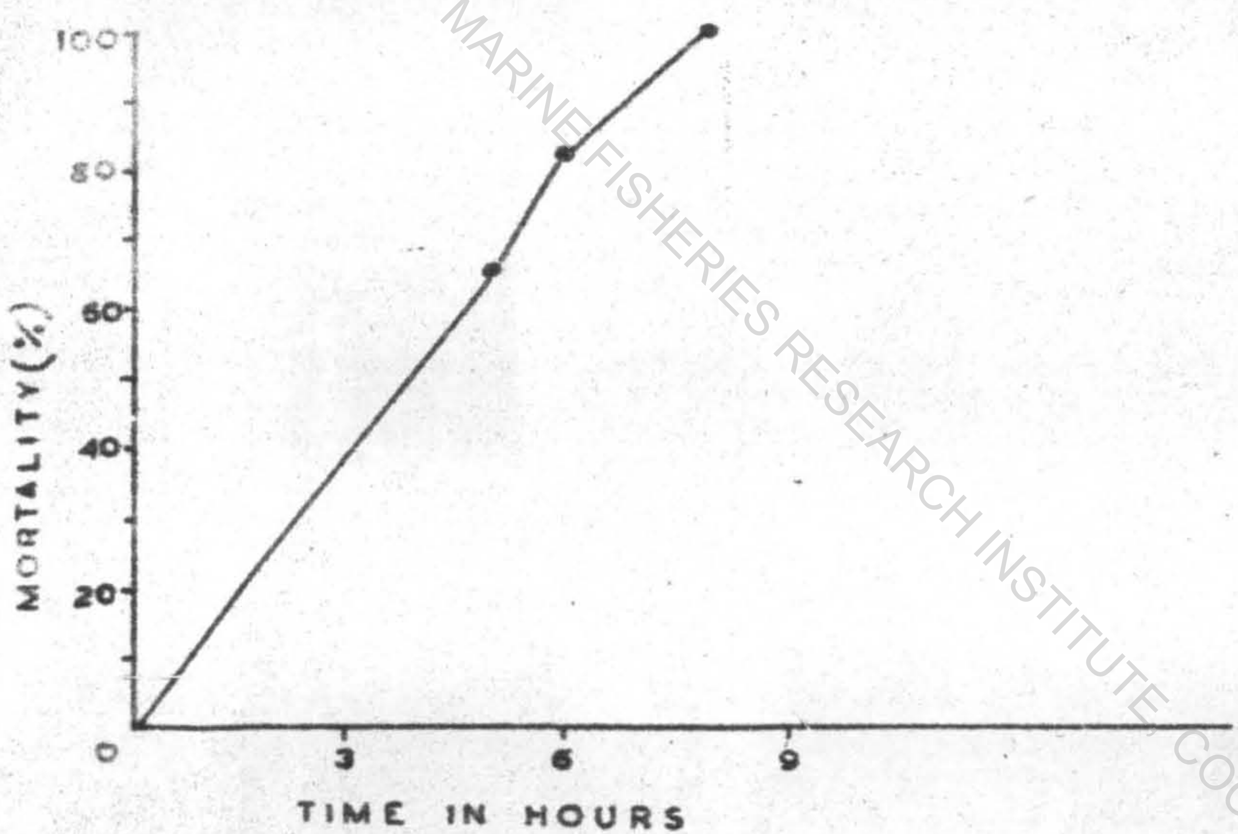
DATE : 15.4.79.



MORTALITY RATE OF <u>LIZA</u> <u>MACROLEPIS</u> (SMITH)

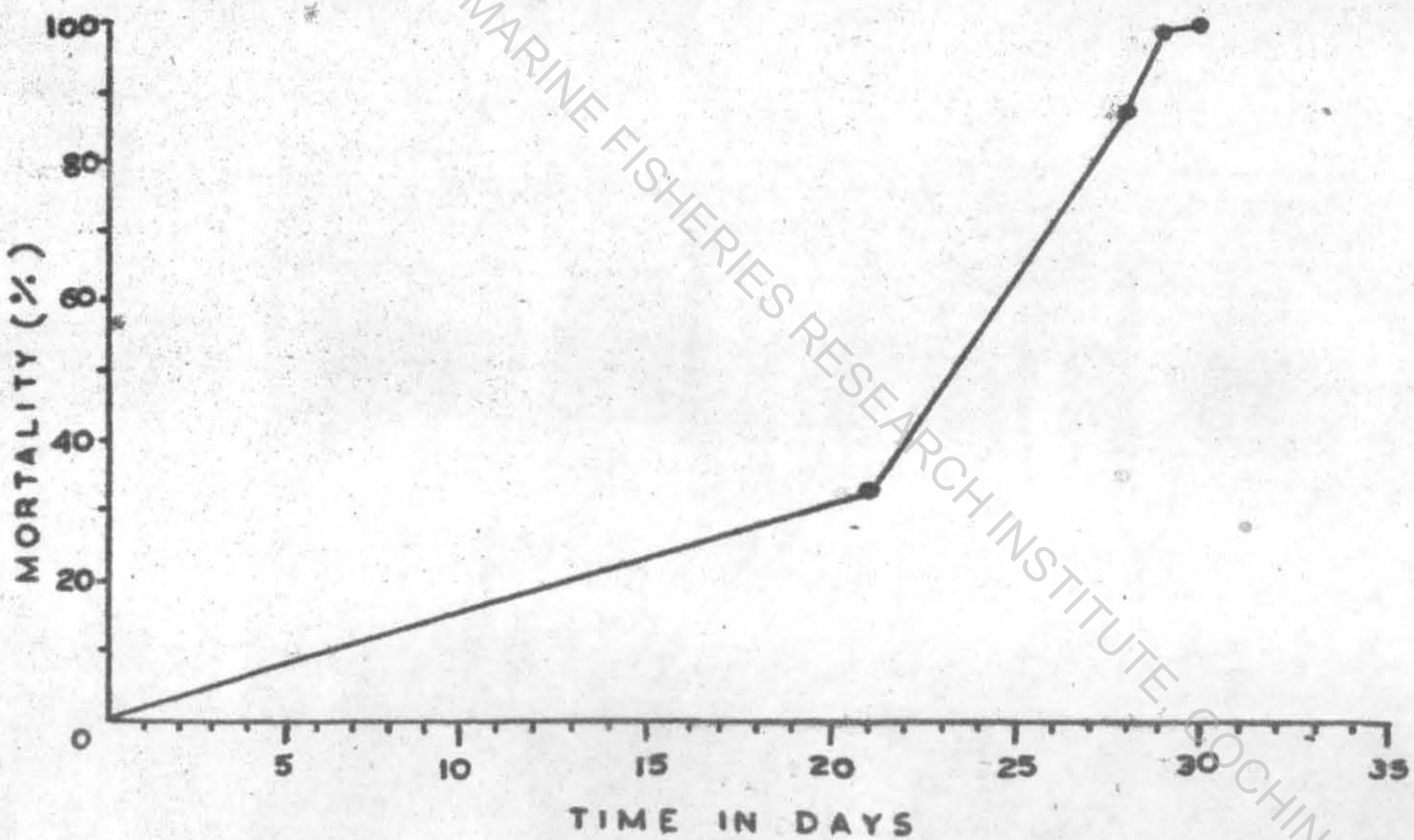
FIG.5

DATE : 10.5.79



MORTALITY RATE OF <u>PERNA</u> <u>VIRIDIS</u> LINNAEUS

FIG. 6 DATE: 15.2.79



MORTALITY RATE OF *PERNA VIRIDIS* LINNAEUS

FIG.7

DATE : 18.7.79

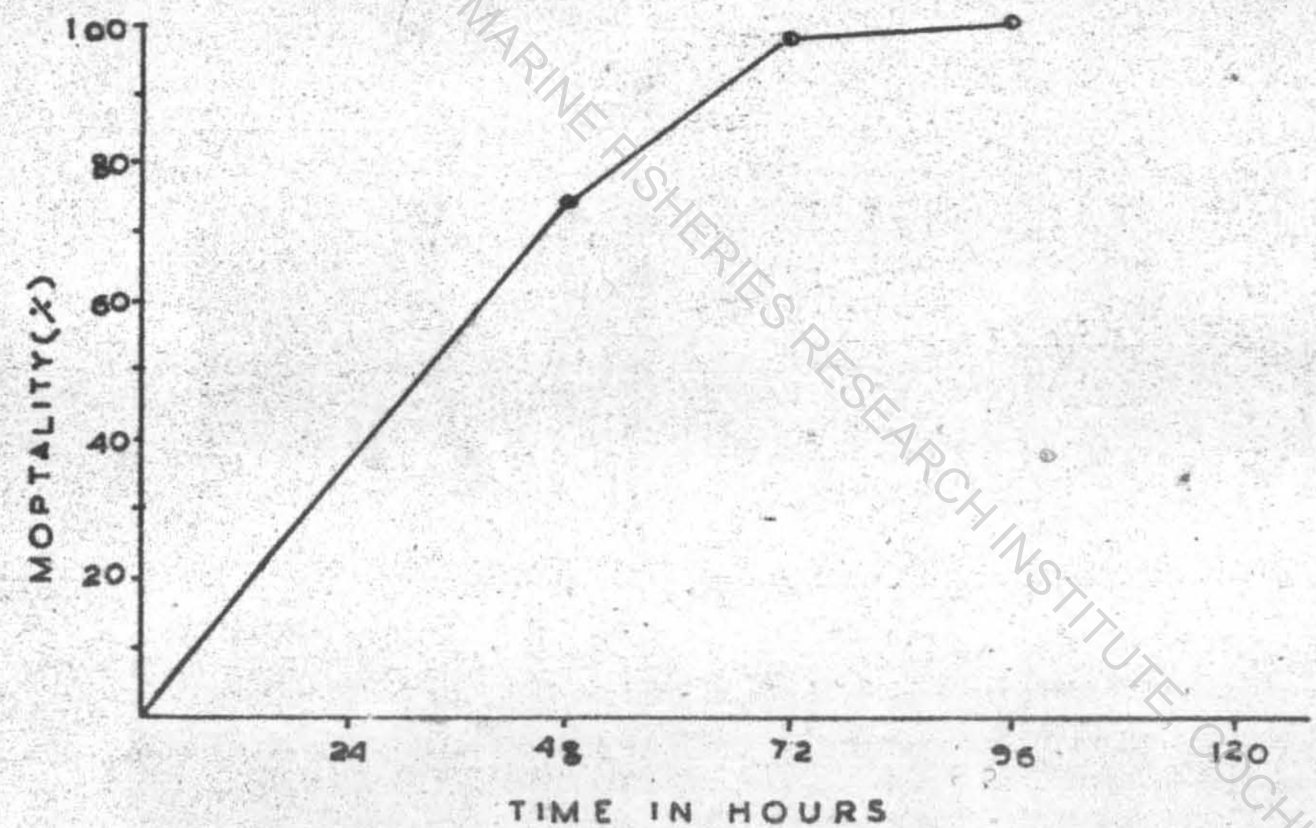


TABLE 2

HYDROLOGICAL CONDITION OF THE WATER (RIVER COCUM) DURING THE TEST PERIOD(JANUARY-JULY 1979)

MONTH		Salinity %		Temperature°C (water)	Dissolved Oxygen ml/litr.	pH
JANUARY	27/1/79	Low tide	3.39	26.2	1.12	7.5
		High tide	6.87	26.5	4.47	7.8
	28/1/79	Low tide	3.38	25.6	0.45	7.4
		High tide	7.60	26.4	4.24	7.9
FEBRUARY	15/2/79	Low tide	6.87	27.5	0.67	7.4
		High tide	14.49	28.0	3.80	8.0
	18/2/79	Low tide	9.65	26.5	0.00	7.5
		High tide	27.97	27.8	3.35	8.2
MARCH	1/3/79	Low tide	13.39	28.2	0.00	7.0
		High tide	27.93	28.5	0.88	8.0
	2/3/79	Low tide	19.86	28.4	0.67	7.5
		High tide	31.27	29.5	4.47	8.2
APRIL	19/4/79	High tide	33.45	31.2	4.91	8.5
		Low tide	23.48	32.0	1.90	7.4
	..	High tide	25.43	31.0	3.80	8.2
		Low tide	13.50	31.2	0.78	8.0

MONTH	SALINITY%		TEMPERATURE °C (Water)	DISSOLVED OXYGEN ml/litr	pH
MAY 15/5/79	High tide	25.89	30.8	4.90	8.0
	Low tide	18.43	29.5	0.45	7.2
,,	High tide	23.48	30.4	4.24	8.0
	Low tide	12.14	30.0	0.36	7.5
JUNE 17/6/79	Low tide	15.82	28.5	0.12	7.0
	High tide	22.30	30.0	1.56	8.0
,,	Low tide	16.30	28.0	0.04	8.0
	High tide	24.20	29.8	1.48	8.2
JULY 18/7/79	Low tide	8.40	27.5	0.06	7.0
	High tide	16.80	29.0	0.22	7.5
,,	Low tide	7.28	28.0	0.04	7.0
	High tide	15.40	29.4	0.20	7.8

(Reprinted from SCIENCE AND CULTURE
Vol. 47, p 304—305, AUGUST, 1981)

An interesting case of blindness of the eyes in mullet, *Liza macrolepis* (Smith) from Adyar estuary, Madras

In most fishes, sight is the dominent sense for seeking and selecting food[1]. This signifies the presence of an eye fully capable of detection of movement and appreciation of form, the necessary prerequisites for the effective discrimination of colour. The primary function of the vertebrate eye is to receive, resolve and respond to light transmitting the resulting stimulus to the brain[2]. The eye has also many diverse functions to perform and is adapted to meet a variety of changing circumstances[3].

During the course of collection of live mullets from Adyar estuary, Madras for experimental study, one specimen of the species *Liza macrolepis* (Smith) collected on 21-6-'79 appeared to be totally blind. Blindness in fishes is of rare occurrence[4]. Therefore, it was thought worthwhile to record this incident where eyes on both sides of the head were affected to cause blindness.

Fishes were caught using a drag net operated by two men. The euryhaline fish under study was alive and measured 97 mm in total length and weighed 8.0 gms. The length and weight of the normal specimen of this species was found to be 97 mm and 8.5 gms. Although, the fish was alive it

Fig. 1. (A) Normal specimen of mullet, *Liza macrolepis* (smith) ; (B) Blind specimen of mullet, *Liza macrolepis* (smith)

was sluggish and mainly depended on algae and planktonic food, that may be drawn in along the water current passing through the opercular chamber. It was of interest to point out that there was no sign of injury in the eyes. It was found that the location of the eyes were covered by a sheet of thin whitish membrane and hence the possibility of predators attack facing to the removal of the eye crust was excluded. Moreover it was observed that the fish was suffered from fin erosion syndrome (Fig. 1).

In reviewing the literature, it was found that various causes have been attributed for the occurrence of blindness in fishes. It has been reported by many earlier workers that blindness may be caused due to predation,

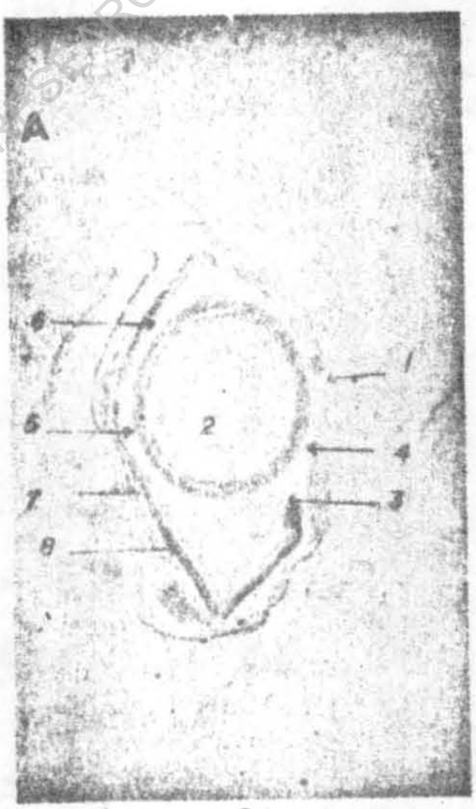


Fig. 2 A. Vertical section of the eye of normal specimen of mullet, *Liza macrolepis* (Smith) : (1) Cornea. (2) Lens. (3) Iris. (4) Aqueous humor. (5) Vitreous humor. (6) Retina. (7) Sclera. (8) Argentea of choroid gland.

genetic factors diseases, and environmental pollution[6-8]. In the light of the above reports and the occurrence of fin erosion syndrome due to pollutants occurring in the river estuary, it would appear that the blindness of the fish under study may be due to pollution induced genetical factors. However, further laboratory experiments are needed to confirm the above conclusion.

For histological studies, the eyes of both normal and blind specimens of mullet, *Liza macrolepis* (Smith) were carefully removed and first fixed in Bouin's fixative and the same were washed in running water till the yellow collour disappears and finally decalcified in 5% EDTA for 48 hours[9]. Vertical sections of the normal and blind eyes were compared and the significant differences are reported here (Fig. 2 A & B).

Fig. 2 B. Vertical section of the eye of blind specimen of mullet, *Liza macrolepis* (Smith):
(1) Accumulation of additional tissues close to cornea. (2) Formation of the iris layer. (3) Compressed lens. (4) Affected vitreous humor. (5) Damaged parts (Retina, sclera and choroid gland) on the posterior end of lens.

The visual systems of euryhaline fishes have been reported earlier[10]. In the present observation, the typical normal eye ball of mullet, *L. macrolepis* is flattened on the anterior face whereas in the case of blind eye, the eye ball is immersed inside the eye socket and covered by a thin sheet of whitish membrane. In the normal eye, the transparent cornea is continuous and well streamlined with a tough flexible opague envelope, the sclera and the presence of encircling band of cartilage whereas in the blind eye the accumulation of additional tissue close to the cornea is seen which may be one of the reasons for the prevention of vision.

In the normal eye, fringing the edge of the lens is the iris and much of the iris is covered externally by a very ductile annular ligament linking the iris to the cornea. The lens is attached dorsally by the suspensory ligament between the cornea and the iris. The enveloping lens is projected for ward into the anterior chamber filled with the aqueous humor. Behind the lens is the posterior chamber filled with the vitreous humor. In the blind eye, the vitreous humor is aggregated and appears like a black patch and due to this formation the eye might have lead to blindness. Blindness has been produced experimentally in some fishes by injecting this chamber with phemerol causing degeneration of the eye[11]. In the blind eye, the lens becomes compressed into a black ball in the centre and pushed backward. The iris instead of holding the edge of the lens, it has grown over the lens and formed a layer below the cornea. In the normal eye, the different parts mainly retina, sclera and argentea of the choroid gland on the posterior end of the lens are more conspicuous whereas in the blind eye they are damaged and not clear.

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The Resources of the Ocean with Special Reference to the Indian Ocean

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Today as ever, the ocean is full of riddles and mysteries. It is quite logical that the exploration of the near ocean has actualy started at the same time as that of the exploration of distant space.

In many countries the number of research ships is increasing, new types of research craft being developed including submarines and bathyscaps; entirely new exploration methods have appeared. Why this hightened attention towards the ocean? Principally because of the possibilities to draw on the varied resources of the ocean? The ocean is an-inexhaustible source of food, minerals, chemicals and power. It may be used for medical and health building purposes. The ocean is a source of potable and industrial waters. Desalting of sea water will permit not only to solve the fresh water problem but also to tap the chemical resources of the ocean which run into staggering figures.

The estimated resources of the ocean should last tens and even hundreds of thousands of years, since they are incomparably richer than all the deposits known on land. As for as the power resources of the ocean are concerned they are virtually inexhaustible. The energy resources of all rivers total 850,000,000 KW, while the energy of the tides is estimated at 1000,000,000 KW. Further more, the source of this energy—the Cosmic mutual attraction forces in the earth-moon-sun system, does not grow weaker with time. Enormous resources of energy are contained in sea waves and in the temperature drop between the upper warm and the lower cold layers of the ocean waters. However the possibility of practical utilisation of these sources of energy has not been tested and for the time being the problem is still in the stage of schematic projects. The by-products are processed into animal feed, fertilisers and industrial raw materials.

The ocean serves man in many other ways as well; as the most important factor shaping clamate and wheather, as a carrier of Sea-borne trade, as a health building factor. It all explains the complex nature and the diversity of the problems of ocenographical science. The Indian ocean was practically un-explored some ten years ago. According to some scientists we know less about the bottom relief of the Indian ocean than about the Moon surface. In this connection as well as in the interests of developing countries on the Indian ocean, a speciai organisation was set up about eight years ago and such expenditions are continuing till now. The Indian oceanographer Shri D. Lal devoted his reports to large scale physicai process in the ocean. On the basis of the information about the distribution of certain 'Long Life' radioactive isotopes in the ocean he calculated the characteristics of the mixing of waters in the ocean. This process is highly important for providing the variable marine organisms with nutritive substances. In this way the physics of the sea borders on the biology and is related to questions which have a bearing on sea fishing industry. The problem of the ocean and atmosphere was sizeable contribution to improving the methods of weather forecasts and establishing the hydrological conditions of the sea.

In recent years Soviet scientists have done quite a lot to develop underwater research facilities to promote an all round investigation of the ocean. The cruises of the research submarine, "severyanta" have been fruitful. The submarine submerged under water using a variety of air mixtures. Several types of hydrostats and submarine glinders including the "Atlanta-1" which was tested in the Batlic Sea, have been developed. Special photo equipment, T.V. and other devices have also been developed.

India with her perennial proclem of population explosion, must look not to her land for salvation but to the sea whose resources are legion. Nowhere else can such huge quantities of excellent food be obtained with so little effort, as from the waters especially from the oceans which cover 71./· of the surface of the globe With an area of 139,295,000 squaire miles Containining 331,000,000 cubic miles of water, the world's oceans provide the highest store house of human food that nature in her bounty has conferred on us. The food production from the oceans can be aptly called 'harvest without sowing'. In fact one of the most promising international scientific developments has been the exploration of the last frontier on the planet, the world's oceans, to solve humanity's eternal problem : hunger. It is estimated that the oceans contain about 80./· of the world's animal life. The exploitation unfolds a vista of immense possibilities to feed the millions. According to some experts, the oceans can supply enough animal protein to satisfy the needs of a world population six limes as large as now, Thus, scientific exploitation of the sea and proper utilisation of the aquatic products provide the ultimate answer to the food problems. Seafoods are an all purpose protein food containing 22 amino acids cemmoniy found in the animal protein food and good proportions of the 8 regarded as essential to human health. Generally all animal proteins have a higher Biological value than plant proteins. Thus, only animal protein can supply man with the whole complex of essential amino acids essential to sustain health.

Fish is one of the most important resources of the waters and it is the cheapest and best source of the animal protein containing all the essential amino acids. The target of the animal protein could there-fore be effectively and economically met by an increase in fish supplies.

India has a large coastline of 5,500 kms, and a continental self of 281,600 sq.

kms. offering considerable scope for establishment of successful fisheries. The continental shelf on the West Coast is narrow in the South but broadens towards the north of Bombay. The shelf on the east coast is narrow, except off the mouths of the Ganges. The wadge bank forms part of the shelf in the extreme south. The Bay of Bengal and the Arabian Sea abound in fishing grounds. Gulfs and Bays all along the coast and a large number of Islands with their mangrove swamps and coral reefs are rich sources of marine life.

Many of the World's great Fisheries are found along the paths of ocean currents that plough the ocean by creating circulation that penetrates to the ocean bottom and cause an upwelling of water, rich in nutrient salts. The Indian waters are a meeting place of 4 ocean currents.

1. The south west monsoon drift
2. The north east monsoon drift
3. The Indian counter current
4. The north equatorial current

The other permanent currents of the Indian ocean are the Equatorial counter current, South Equatorial current, Mozambique, Agulhas and Somalia currents which wash ths east coast of Africa. The confluence of the ocean currents near India keeps her poised on a thresh-old of copious supplies of sea-foods.

Sunlight plays a role of dual importance in aquatic life. It is an essential element of the life of fish and other marine animals. Response of marine plants to light, their propagation and growth, develop euphotic zones in which phytoplankton and planktonic algae flourish. This is Nature's fish food. The other prominent role of sunlight is on the fertilization and maturity of fish eggs. India situated in a location that extends from the hottest tropical regions upwards, possesses waters that are bathed in sunlight.

More than 1800 distinct species of fish are known to exist in Indian waters. Of these 500 species classified in 16 groups can be considered the commercially important edible fishes. In fishing, depth zone areas are divided into inshore waters which extend upto a pressure range of 2 atmospheres (i.e.) 2066 grams pressure per square centimeter that stretches upto 10 fathoms; offshore waters which extend upto a pressure range of 6 atmospheres (i.e.) 6,198 grams pressure per square centimetre that stretches upto 30 fathoms; and deep sea which represents depth from 30 fathoms beyond. Fertile fishing grounds abound in the Indian Ocean. The Indian waters possess 14 rich and fecund fishing grounds. Their systamatic exploitation will yield very rewarding results. India's annual fish production is little more than one million tonnes, According to the estimate of the National Institute of Oceanography the present yield from Indian ocean fisheries can be increased to at least 10 million tonnes in the next few years and is capable of a ten fold incease towards the close of the century.

The significant achievements of Inde-Norwegian Project in regard to exploratory fishing are the discoveries of new fishing grounds (a) the location of large fishing grounds of Kalva in the 45-50 fathoms line. (b) the location of the synagris fishing grounds off Alleppey-Cochin in the 25-40 fathoms range. (c) the location of the potential deep water prawns and lobsters in the 150-200 fathoms range off Quilon-Alleppey region. (d) the shrimp beds off Quilon-Kayankulam region and the Cannanore Pazhayangadi region. (e) the development of the purse seine fishing for cat fish in the Gulf of Mannar, (f) the location of prawn beds off Mandapam in the Gulf of Mannar. It is worth noting that practically all the afore mentioned new grounds are deep sea fishing grounds for prawns in deep waters beyond 30 fathom line. Per Sandven remarks (1959) that in the Arabian Sea out side the Malabar coast are found some of the richest prawn grounds in the world. In terms of value and development the sea based shrimp fisheries of India occupy a singnificant position. About 100,000 tonnes of shrimp are captured every year by Indian fisher men. The Indian seafood industry has registered an impressive growth, in exports at an average annual growth rate of 14.9·/. as against the rise of world exports of seafood of 8.2·/.. India's annual earning from export of seafoods can touch Rs. 822.61 million by 1978-79. This will be in addition to the current export earnings which will aggregate to a total annual earning of Rs. 1,272.61 million by 1978-79. Besides shrimps, India can export in substantial quantities other marine products like Lobster, mackerel, Sardine, Tuna, Bombay Duck, Eel, Crab, Oyster, Mussels, froglegs, fish meal, fish maws, sharkfins and seaweeds.

Most countries in the world have been paying special attention to the development of their fisheries. As a result, the World production of aquatic products, which was just 21.1 million tonnes in 1950 had more than doubled to 52.4 million tonnes in 1965. Biologists have estimated that the seas of the world could sustain an annual catch of between 400 and 500 million tonnes of fish. It may be mentioned here that the resources of the Indian ocean have just begun to be exploited and these at present account for only about two million tonnes of the world's production. It is clear that the food in the sea is plenty and varied. It is left to the ingenuity and adaptability of man to make use of these immense resources which nature in her bounty has conferred on us.

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Life in the deep sea

THE deep sea, by far the largest of biological environments, is also the least studied. It is cold under high hydrostatic pressure, dark and poor in food resources. Yet animals and bacteria can be found to exist at all depths. Bacteria inhabit the mud on the sea floor and are sparsely distributed throughout the bulk of the water. Some animals like the sea anemones, sea cucumbers, bivalves, worms and prawns dwell on the sea floor while others such as the fish, squids, prawns and single-celled animals are the residents of midwater region.

Obtaining sufficient food is a major problem for all animals living in the deep sea Animals eat preformed organic material and in the sea this is produced by microscopic plants floating on the surface of the sunlit waters. Plants consume some of the organic materials they photo-synthesise, when the intensity of illumination falls below a certain level Net synthesis of organic material is therefore almost nil. In the turbid waters of the ocean, a net synthesis of organic material occurs only at depths down to 45 metres (147 feet). In clearer oceanic waters the net synthesis may proceed at depths down to 100 metres (327 feet). However, these depths should be contrasted with the ocean's average depth. The greatest depth is about 10,800 metres (35,433 feet) in the Marina Trench in the Pacific.

It is probably correct to describe the deep sea as a desert. Its inhabitants acquire food by catching what falls from the productive surface waters, or by preying on what passes by. The concentration of deep living planktonic animals (animals which are so small that their distribution is largely) may be a thousandth of the surface value. The deep sea is also a cold desert with temperatures between (4°C-0°C). There is however, abundant dissolved oxygen to support organisms.

Hydrostatic pressure increases by one atmosphere (one atmosphere means 14.7 pounds per square inch or 1.0332 kg. per square centimetre) for each ten metres (32.8 feet) depth. So the average pressure in the sea is 380 atmospheres and the greatest pressure is approximately 11,000 atmospheres. Pressure of this order is sufficient to compress molecules closer together. It is through molecular volume changes that pressure exerts its profound physiological effects. We are not here concerned with compressibility of gases and the problems of "deep living man and other mammals". Hydrostatic pressure acts uniformly in all directions and the tissues of deep sea animals are compressed in much the same way as the surrounding sea water. High pressure, like other extreme physical treatment such as high temperature or intense radiation, alters molecular structures and "poisons" a system. Experiments with surface living organisms have shown that deep sea pressures inhibit many fundamental physiological process.

Since we have good reasons to believe that deep sea organisms are evolved from shallow living ancestors, we must conclude that the evolution involved changes in molecular structures to suit the habitat An extremely important process in shallow living organisms sensitive to deep sea pressures is the process of cell division. Organisms grow from a single cell egg by increasing their size and dividing into two. The division process involves a mechanical 'contractile' stage which the high pressure inhibits. It appears that high pressure renders useless the large molecules which perform the mechanical process of division. Clearly, we must expect deep sea organisms to have acquired specially modified molecules which work at high pressures.

Oxygen consumption (a measure of respiration) and many other biochemical reactions are affected by deep sea pressures. It is often the case with shallow organisms that lowering of the temperature enhances the inhibitory effect already obtained with high pressure. So the deep sea would appear to confront animals with an intensely inhibitory environment. Complex systems like muscle and nerves are affected by high pressures in many different ways.

High pressure adaptation is a highly complex process. C.E. Zo Bell (1940), the American scientist has pioneered experimental studies in this field by bringing deep sea bacteria to the surface. He has demonstrated that despite experiencing temporary decompression, some bacteria grow preferentially at their normal high pressure. These forms are called "barrophilic".

Since the food supply of fish fundamentally depends upon plankton, much importance has been given to recover deep sea plankton at constant temperatures and pressures for study under controlled conditions on board a ship. The intention is to measure the physiological performance of planktonic animals from various depths to learn something about their pressure-tolerance and energy (food) requirements.

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Whales, dolphins and porpoises of the Indian coasts

MAMMALS which feed their young with milk secreted by mammary glands rank high in the scale of evolution. Some mammals have adapted themselves to an aquatic mode of life. Among them the Cetaceans are the commercially important group. They are predominantly marine, though a few of them have preferred fresh-water or brackish water environment. The aquatic mode of life has greatly influenced their anatomical features. Almost all of them have fish-like bodies but are distinguishable from the latter by the absence of gills.

In India, however, much attention has not been paid to whales found along the coasts. Occasional strandings of whales have been reported by biologists. However, dolphins and porpoises occur in good numbers and are caught by fishermen as they cause considerable damage to nets. Besides supplying meat, they can also be of considerable assistance in improving communications in navigation.

The order Cetacea is divided into three suborders: (1) Archaeoceti, exclusively fossil, (2) Mysticeti and (3) Odontoceti, on the basis of absence or presence of teeth in the adult animal.

Whales

The suborder Mysticeti includes whales which are considered to be the giants of the seas. The term whale does not indicate a natural division of the order and sometimes is used to mean the whole species of the Cetacea, irrespective of their sizes. They are warm-blooded and air breathing. Their blubber and fats are prized commercially for use in soap and candle-making industries.

There are three families of whales but only two of them include most of the commercially important species. They are the right whales of the family Balaenidae, and rorquals and humpback whales of the family Balaenopteridae. The whales under the family Balaenopteridae have a series of baleen plates; they feed on planktonic food obtained by filtration of water through these plates. Of Balaenopteridae family five species are recorded in Indian waters, viz, the Blue whale, Balaenoptera musculus; the Fin whale, B. physalus; the Pike whale, B aecutorostrata, B. Indica and the Sei whale, B. borealis. They differ in size, colour and habits. Among the five species the Blue whale B. musculus, is the largest living creature in the sea. It can attain a length of 30.5 m or more and a weight of 135 tonnes. Yet it feeds on the plankton of the sea.

The suborder Odontoceti is characterised by the absence of baleen plates and by the presence of teeth. It comprises seven families Stenidae, Phocaenidae, Delphinidae Ziphidae, Monodontidae, Physeteridae and Platanistidae. An interesting example is the sperm whale, Physeter catodon, recorded from Indian waters.

It grows upto 18m and is the most powerful diver of all whales. Mention may also be made of the vicious killers in the sea—the killer whale, Orcinus orca and the false killer whale. Pseudorca craissidens They are exceptionally ferocious and dangerous predators of the seas. The Pilot whale, Globicephala macrorhyncha, is another common form, the oil of which is a fine lubricant. Recently, about 147 numbers belonging to this species were stranded off Manapadu in Tamil Nadu. The habit of stranding enmass in shallow waters is due to the inability of Pilot whales in locating gently inclined sea floors in shallow waters.

Dolphins

There are eighty species of toothed whales. Only members of the family Delphinidae are called Dolphins. Dolphins have either an obvious elongated beak or a globose often bulging forehead as in Pilot whales. The dorsal fin is high and usually falcate. Conically curved teeth may range from small and slender to thick and heavy in ralative sizes. They are fish eaters and in captivity can eat upto 22.5 Kg of fish a day.

The cosmopolitan common dolphin, Delphinus delphis, grows upto eight meters. They are slender and graceful. The colour is black above and white below. Dolphins can be readily distinguished from the porpoises, the farmer have beaks. Though considered to be friendly creatures, they are often hunted.

Porpoises

Porpoise is a broad term usualy used to distinguish relatively small toothed whales. Except the members of the two families, Stenidae and Delphinidae, all members of the family phocaenidae are referred to as porpoises. They are found in all seas of the world at a wide range of temperatures. They eat a variety of animal foods. They do not live exclusively near the surface, instead they may dive to great depths for food. The porpoise, Phocaena phocaena, found in Indian coastal waters, is the commonest of all the Cetaceans.

Not much is known of the biology of wild porpoises. The recent international symposium on the biology of Cetaceans has brought out more details concerning the use of sounds by porpoises for echo location and inter and intra-specific transfer of information.

The British Museum of Natural History publishers from time to time strandings of whales, dolphins and porpoises.

An international commission has also been formed to study variaus aspects of Cetaceans and to suggest conservational measures to protect them.

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Oil pollution in the sea

IN recent years pollution of the environment has become an important topic for national and international consideration. Because of its impact on society pollution has attracted the attention of scientists and, seeing the present calamity, even of the common man.

Pollution can be defined as any substance added to the environment as a result of men's activities which has a measurable and generally detrimental effect upon the environment. In a more restricted sense the term pollution is used mainly when the changes are harmful or in conflict with other uses of the environment. Marine pollution is defiined as discharge of waste substances into the sea resulting harm to living resources, hazards to human health, hindrance to fishery and impairment of quality for use of sea water. Marine pollution is associated with the changes in the physical, chemical and biological conditions of the sea waters.

In the marine environment oil pollution appears to be the main problem and it is a threat to the marine ecosystem and to the fisheries of the world. Oil pollution of harbours, bays, beaches and the open ocean has been increasing day by day.

The main oil products discharged in to the marine environment from the shipping operations both on the high seas and at the coastal belt are the light diesel oil, high-speed diesel and crude petroleum. Such extensive spreading of oil affects the floating plantation and also the marine life along the beaches. In areas of oil exploration, fishing gear and craft operations are also affected by crude oil and lumps of oily tar. The fish catches have to be discarded because of tainting. Wastes from oil refineries and discharged petroleum from ships also cause heavy damage to fishery.

Oil pollution comes from many sources; oily wastes from oilfields or refineries near the coast produce local problems in these areas. Some of it comes from oil tankers, ships and offshore oil wells.

The dispersion of oil and its persistance in the sea are affected by a number of factors—the kind of oil, its specific gravity, chemical composition and the state in which it is discharged in to the sea. Water currents and temperature are also important in determining the location and duration of oil slicks in the sea water.

Two of the most publicised oil spills in recent years were the wreck of the tanker 'Torrey Canyon' (1967) which caused damage to English and French coasts and the blow out of an oil well at Santa Barbara California in the USA. Both of these disasters occurred offshore in relatively deep waters, but caused extensive destruction of coastal marine fauna. However, it was impossible to distinguish between the effects of the oil its[illegible] nd of the detergents and dispersants used in an effort to control the oil pollution. On 18th June 1973, *M. V. Cosmos Pioneer* broke into two near Porbandar due to rough weather releasing 18,000 tons of light diesel oil. It caused considerable harm to the pelagic fisheries of the Gujarat coast.

The harbours and beaches of both west and east coasts of India are polluted to some degree with various kinds of oily and tarry substances. Occurence of tar-like lumps were noticed and reported by Dr. N. K. Panikkar (1970) in the Goa beaches. Owing to the importance of beaches and visible danger of pollution, extensive studies of this material in the various beaches of India are being carried out by the National Institute of Oceanography. In the mean time the Central Marine Fisheries Research Institute is also investigating the aspects of marine pollution and its effects on fisheries. Recently heaps of dead fish were washed ashore between Dabolim and Velcao coast in Goa. It created a big scare among the local people, especially the fishermen. It was believed that the mortality of fish was due to dangerous effluent discharge from the Zurai Agro-chemical Fertiliser Factory. Large scale fish kills have also been reported by B.F. Chapgar (1971) near the Bombay coast. A knowledge of the distribution of the oil and the location of its concentration is necessary before effective measures can be taken to confine, control and clean up the oil slicks. Reliable information on the thickness of oil film is required to estimate the volume of slick essential for an assessment of its impact on marine life and environment. Experiments conducted in the east coast of USA by Drs. J.P. Hollinger and R. A. Mennella (1974) have shown that microwave radiometry offers a means of measuring the distribution of oil on the sea surface and of measuring their volumes on an all-weather day-and-night basis.

Accidental discharge of oil can be cleaned up by several methods. But, as with all pollutents, the only effective measure for controlling contamination by oil of the aquatic environment is the prevention of avoidable spills and releases. Among the oil removal methods in use today, mechanical containment and removal of oil appear ideal from the point of view of avoiding long term biological damage.

P. NAMMALWAR

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Sea-Food Industry In India

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It is now twenty years since the sea food industry in India began in 1953. Export of sea food has risen from 11,161 tonnes valued Rs. 42 million in 1962-63 to 38,903 tonnes valued Rs. 597 million during 1972-73. It is estimated that exports of sea foods could be stepped up to 45,850 tonnes valued Rs. 650 million in 1976-77 and 130,000 tonnes valued Rs. 12,000 million by 1978-79.

The world resources of marine products have been estimated at about 120 million tonnes of which only 55% is now being utilised The Indian Ocean alone is estimated to provide a catch of 12 to 14 million tonnes of which 15% alone is now being exploited. Moreover, the Indian Ocean is rich in many varieties of marine products particularly along the south-west coast of India where we have the richest prawn fiishing grounds in the world. Today India is one of the seven leading fish producing countries of the world and her main exports are frozen, canned and dried shrimps, frozen lobster-tails, frog legs, shark fins, fish maws canned and dried fish. The Indian fishing grounds are rich in other marine products like sardines, mackerels, perches, breams, tuna, Bombay duck, pompfret, eel, anchoviella, cat-fish, crabs, oysters and mussels which have not yet found their way on a large scale export into the inter-national markets.

Marine products has been identified as one of items with great growth potential. The Marine Products Exports Development Authority (MPEDA) corporating with the representatives of the Government of India from the Ministries of Foreign Trade, Agriculture, Finance, Industrial Development, Shipping and Transport and the representatives of maritime states have been bestowing serious attention of the integrated development of the fishing and sea food export industry.

The International Shrimp Council (ICS), a world wide trade association of shrimp products, exporters and others interested in the marketing of shrimp has been formed in the United States during 1968 to create an ever-increasing demand for shrimps in the States and eventually to develop a world market.

India's efforts to add to her knowledge of the Indian ocean will depend on her ability to secure the necessary ships to conduct the oceanic exploration. According to the survey reports of the International Indian Ocean Expedition (1960-65) excellent and varied fish shoals have been located in the Arabian sea and some parts of the Bay of Bengal and other regions of the Indian Ocean The new fishing grounds located by the Indo-Norwegian Project are really the virtual 'gold mines' in the sea with an unlimited quantity of fish resources. The discovery of old shoreline by the Scientists of National Institute of Oceanography in the West Coast are the localities where extensive deposits of economically valuable minerals like monazite, ilmenite and many other minerals are found. Considerable quantities of minerals such as shells, iron sands, tin, diamonds, gold, silver, platinum, manganese, titanium and sulphur are present at the bottom of the ocean yet waiting to be picked up.

There is a good demand for the Indian frozen varieties, shrimps, frog legs and lobster tails in U. S. A., Japan, Australia, Belgium, France, Switzerland and West European countries. Dried fish and prawns had a favourable market in the foreign countries mainly Ceylon, Hongkong, Malaya, Singapore and some of the African Countries. Kerala ranks first in fish yield followed by Maharastra and Tamil Nadu and West Bengal. These States including Gujarat are trying to develop their yield by planing and implementing various projects.

In the fishing trade the big industrial giants like Tatas, DCM and Birlas have also entered. Not to be left out are Union Carbide, the Indian Tobacco Company, Britannia Biscuits, Parry's Rallis (India) Ltd., Ghowglays Ltd. and Gujarat Fisheries Ltd. They have the means to go in for deep-sea fishing, with the result that smaller fishermen are unable to compete successfully with them. Recently there was a fear among the poor fishermen who led a protest against the use of trawlers by these concerns. Nearly 5,000 mechanised boats and 300 large trawlers for deep sea fishing will be pressed into operation by the end of the Fifth Plan to boost the earnings from the export of sea foods to Rs. 120 crores. Their allotment to the fishing trade will be decided by a Government panel, with preference given to State Fisheries. One of the reasons for the development of sea food export industry and developmental programmes adopted by the Government of India is by inviting International Fishing Organisations from U.S.A., Japan and Norway to help, modernise the industry to enter in the foreign markets on a competitive bass- With the expansion of exports, the composition of the products and markets have also undergone a noticeable change. The fulfilment of this increasing exports depends on the efforts which are put forth to strengthen the foundations of the industry to enable it successfully meet the challenging demands of export. The primary and the most important tasks are the provisions of more mechanised trawels, enlargement of boat building yards and repair facilities, development of fishing harbours, transport facilities, training of skippers and other personnel, stepping up the production in fish landings and processing centres etc.

Our fishery resources are potentially the richest in the world. The Sea Food Exporters Association. the only All India Representative body and the Marine Products Export Development Authority (MPEDA) being a common body would be well advised to promote a campaign and provide sufficient incentives for the development of the Indian sea food industry. The resources of the sea could be our answer to the recurring threats of famine. The ocean can supply enough animal proteins to satisfy the needs of the larger population of the world.

A proper exploitation of our vast resources in the sea by employing machanised methods and catching all types of fish, their utilisation by extending our freezing and canning industries to fish other than prawn, modernisation of fish curing industries and economic use of trash fish and other by-products are sure to open out a bright future to our fishing industry. This will not only improve the economic position of the country but also contribute its share in alleviating the problems of shortage of food materials and serve to uplift the socio-economic conditions of the lakhs of fishermen engaged in the industry.

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OCEAN—A SOLUTION FOR INDIA AND THE WORLD

P. NAMMALWAR

The World's ocean produce about 80% of all proteins, yet so far man is using only an insignificant part of these riches. In recent years marine biology and oceanography, the sciences which help man to tap the waelth of this living treasure store in the most effective manner by turning the seas and oceans into a gigantic laboratory. Because of the world-wide continuity of the oceans and their conditions, International collaboration is essential so that comparative studies may be made on a broad geographical scale. Collaboration is desirable, also in order to achieve an adequate research effort on selected basic probelems.

AN essential way of estimating natural resources is the direct method of studying the resources themselves in those situations where such direct estimation is feasible. (Usually, this implies the existence of a commercial fishery). Research on resources cannot be carried out profitably in isolation, however, this is a principle which is recognised in the Fisheries Institutes where much important fundamental research has been done and where, for instance, a considerable effort is devoted to research on hydrography and planktonology. The yield of commercial fisheries is largely determined by the pattern of mortality, reproduction, migration and shoaling behaviour which, in their turn, are dependant on food supply and other biological, physical and chemical features of the marine environment of which fish form a part. Success inforecasting and regulating fisheries will depend on an adequate understanding of the whole eco-system.

Many fishery biologists have pointed out that serious obstacle to progress in fisheries research is the unsatisfactory state of present knowledge of the ecology and physiology of marine organisms in general. The investigations should be directed, therefore, towards an improvement of our understanding of the basic ecological mechanisms which control the abundance, distribution and productivity of marine organisms, of all kinds throughout the tropic chain in the sea.

There is an urgent need to acquire this fundamental knowledge in the regions which are easily accessible to man, such as the coastal areas, the littoral zones, the waters of the continental shelf, the estuaries, lagoons, and mangrove swamps. These are the areas in which man is already imposing changes through exploitation, pollution, land reclamation, and other activities. There are also the regions which offer the most immediate prospects of improving resources through human intervention. The importance of studies in the open ocean should not be overlooked, however. The detection and measurement of ecological mechanisms will be dependant, in part, on the opportunity to make comparisons, between different environments; coastal and oceanic, continental shelf and slope, tropical, sub-tropical and temperate. The individual contribution should, collectively, provide the material for such comparative studies. The programme should form a sufficiently representative time series for the elucidation of general principles and it is essential that long-term variation shall be studied as this a major source of difficulty in planning the efficient utilization of marine resources in many parts of the world. The programme should be implemented through a co-ordination of the activities of laboratories rather than by a large international survey. It is hoped, however, that the basic methods and objectives of the programme will be incorporated into such surveys in the future, particularly in expeditions to little known part of the seas. There are already in existence a number of well developed international organizations in marine sciences, particularly in fishery biology, marine biology and oceanography.

The study of seasonal variation, one of the most consistent features of biological events in the sea is the seasonal cycling of organisms and nutrients. It is clear that there is a wide range of geographical variation in the magnitude, regularity on pattern of these cycles, but even the basic description of them is known for only a few localities in which classical studies have been carried out. Although seasonal variation is relatively slight in many tropical areas, one of the main objectives would be the detection and analysis of the factors which maintain stability in these areas compared with those which result in maximal variation in high latitudes. It is suggested that such comparative studies would contribute towards the detection and understanding of controlling mechanism will be defined in the form, perhaps, of traverses stretching from the shore to the seaward limit attainable with the available ships and manpower.

Having determined the basic objectives on methods including the possibility of defining standard of inter-comparable techniques, it is fortunate that number of national and international working groups are already considering these problems. The International Biological Programme (IBP) has taken up the experimental and field studies in consultation with international organisations such as, Scientific Committtee on Oceanic Research (SCOR), International Oceanographic Council (IOC), Indo-Pacific Fisheries Council (IPFC), United Nations Educational, Scientific and Cultural Organisation (UNESCO) and Food and Agricultural Organisation (FAO).

There is an immediate need for an active and major research programme for the development of methods of study of biological productivity in the sea. Productivity of the sea can be defined as the capacity to produce and is commonly used as a qualitative term for indicating the fertility of any ocean region. Indeed, most biological studies relating to controlling factors lead to and are essential to an elucidation of the problem of quantitative and qualitative production of plants or animals in the sea. Studies pertaining to production in the sea are of vital interest to several marine sciences, particularly to the physical, chemical, biological or geological, because of their bearing on the extent, time and spatial distribution of organic and inorganic constituents of the water and of the bottom. The need to improve knowledge of the part played by the benthos in the production of organic matter is being neglected. And it is essential to select these research topics in which methods and knowledge had reached the stage where international co-operation is likely to be fruitful. The problems of sampling and estimating production and turn over the benthos seems to be formidable that there is some doubt about the feasibility at this stage of study on the benthos. However, assessments of marine productivity which ignores the benthos especially and of the coastal and inshore regions too. So it will be necessary to make a special study on benthos for the analysis of spatial and seasonal variation.

A joint panel of New Oceanographic Tables and Standards has been set up by Scientific Committee on Oceanic Research (SCOR) considers the intercomparison of measurements of salinity, temperature, chlorinity, density, conductivity and refractive index. It has already drawn up recommendations for the standardization of conductivity measurements and for the relations of these to chlorinity. It is highly desirable that stability and mixed layer depths shall be studied as background for example, to the investigation of phytoplankton blooms and nutrient circulation. Water currents are of major biological importance through the transport of nutrients and organisms. New methods have been developed recently for the determination of reactive phosphorus, nitrate and other nutrients (ammonia—nitrogen) in the sea-water. There are relatively large amounts of dissolved organic substances in sea water, but very little is known about temporal and spatial variations of this material, together with organic detritus, in heterotrophic growth.

The measurement of chlorophyll provides one of the best means of estimating the total plant material in the sea. The spectrophotometric method has become standard and recent work has led to improvements in methods of extracting the pigment, in calibration and the equations used to express the results as chlorophyll. It might be thought that the total of all phytosynthetic pigments should be measured in laboratories with suitable facilities and an attempt made to distinguish between dead and living phytoplankton. The uptake of C^{14} must be used to measure photosynthesis in oligotrophic areas though the simple method of measuring oxygen production may be adequate in autotrophic zones. The problems of quantitative sampling of zooplankton are extremely difficult and so a thorough programme of research into methods and their comparability is essential. It may be necessary perhaps two nets with different meshes combined in one sampler which will provide an adequate sample of the majority of the herbivores. It is important that such a sampler shall be suitable for use from small ships as well as big ones, there may be strong practical as well as scientific advantages in using a high speed sampler. In addition to counts and identifications it will be necessary to express the results in terms of weight of herbivore matter under a unit area or in a unit volume of water.

It has been necessary to select organisms such as fish which are most likely to yield profitable results. Since the food supply of fish fundamentally depends upon plankton, the importance of plankton to fisheries is basic. The richness of plankton production depends on the mixing of the waters due to the upwelling process so that nutrient rich water from the deeper layers is brought to the surface layers where the fish can use it. The richest fisheries of the world are related to the areas of richest plankton production and are on the continental shelves, where there is good feeding and depths which can be economically fished. Insufficient mixing of the water masses is the most important cause for the poor fisheries due to inadequate nutrients for plant growth and so paucity of the plant plankton (phytoplankton) to animal plankton (zooplankton) as food for the fish. Ways can be found to extend these studies to all those kinds of organisms, many of them in the benthos, which are used by man or which are potentially valuable as resources.

In general, the objective would be to study the place of fish, and of other resource stocks, in the trophic network in the sea with the emphasis on seasonal and spatial variations. It will be necessary to distinguish between those stocks which are used by man and those which are not. Information about the first is provided by fisherman, for the second, other methods are needed. In the fishes, areas of the seas, the catch per unit effort by statistical squares is available for a variety of species. The collection of fisheries statistics has greatly improved in many regions. Estimation of abundance derived from fishery statistics should be checked by other methods, including egg and larval surveys. In the unexploited areas, such surveys might be supplemented by acoustic techniques. Both methods could be used from research vessels of marine biological as well as fisheries institutes.

The studies of biological production outlined above would be of limited value without a basic knowledge of the distribution and abundance of the most important species and communities. In some areas this knowledge exists or its foundations are well laid, in others it will be necessary to solve the most fundamental problems of taxonomy and morphology. For these reasons, and because each marine situation presents its own local problems, the work should have a quantitative basis sufficient to determine the relative abundance of different species and to allow the combination of results towards biogeographical atlases. Special attention should be paid to fish eggs and larvae, their food and predators, and the detention and plotting of unconventional resources as well as those which are exploited by man. Attempts should be made to ensure that bacteria, fixed algae and the benthic animals are adequately studied. The kind of field observations are designed to provide the basic material for an analysis of spatial and temporal variations in some of the major biological elements of the sea. The results should provide some of the principal terms required for the formulation and testing of mathematical models of marine productivity.

One topic is requiring for the estimation of productive rates in animal populations as a parallel to the estimation of photosynthetic production. The study of nitrogen as a primary nutrient should not be divorced from knowledge of nitrifying bacteria, involving work on populations in the field as well as metabolic studies in the laboratory. Nutrients are estimated in the sea by chemical methods, but we need to know whether they are all usable by organisms ; biological tests or assays may be necessary to test this point. Dissolved organic substances should be investigated in relation to particular organic material in living organisms and detritus (this is one of the topics in which spatial and temporal variations may be particularly important). The chemistry of excretion by both plants and animals should be studied in this context.

There is a great deal of information about the nutritional requirements and general physiology of a few organisms. However, we are entirely ignorant of the food and physiology of important organisms in many marine communities. Although benthic animals and some of the planktonic herbivores may be attractive particularly urgent attention as they are so numerous and their part in the circulation of organic material must be very great indeed. The blue green algae and seaweeds as far as possible their physiological studies should be performed on organisms taken recently from the sea and kept in very dilute media approximating to natural sea water and similar to those occurring in the sea. An important objective of such experimental physiology should be the study of seasonal and other temporal changes. For example, it is known that growth factors are important in diatom development and it is thought that growth requirements differ in different phases of the life cycle, but very little is known of any spatial or temporal growth promotion substances in the sea. There is insufficient knowledge about internal waves in the sea and their effect on the distribution and abundance of organisms; these effects may be particularly important in considering the differences between shelf and slopes regions.

There will be full collaboration between physical and biological oceanographers as in any marine programmes, but there are special topics in which joint work is particularly important. One of the programmes of UNESCO and FAO is the International Indian Ocean Expedition (IIOE—1960-65) which brought us knowledge about the Indian waters; the highest productivity of the Arabian Sea is strongly supported by oceanographical investigations that the waters of the Arabian Sea are continuously enriched by upwelling and related phenomenon which bring the richer nutrient water from below to the surface and are able to support heavy fish populations. Hence, nearly three fourths of the total sea production is from the west coast. In contrast to this, waters of Bay of Bengal are of a somewhat static character with a comparatively higher temperature, lower amount of nutrient salts, lower plankton production and consequently lower quantity of fish catches from the east coast.

It is high time that the Advisory committee on Marine Resources Research (ACMRR) and the Food and Agricultural Organisation (FAO) should investigate the possibility of developing world programme of Marine Research so that ocean wealth can be exploited at the maximum to meet the minimum requirements of the comonn man.

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Present Status and Problems of Fishermen in the Marine Fishing Industry

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With rising pressure on food producing land resources, an increasing share of future food supply needs, especially of developing countries like India may have to be met from fisheries. The present study focuses on the prevailing problems connected to the fishing populations in our rural coastal regions and the crucial socio-economic problems affecting peace and stability in our country.

The total fishermen population of India was about 55.8 million, representing about one percent of the total population of the country. Along the coast line live around 32.8 million fisher folk. About one million fishermen of the country have distinct tradition of their own. They belong to all the major religions namely Hindu, Christian and Islam and to several communities which differ from state to state.

In most countries, fishing makes a small contribution to national income. Large segments of the population in the coastal areas of our country depend for their livelihood exclusively on fisheries.

As human food, fish and shell fish are considered exceptionally valuable from a nutritional stand point, primarily because it contains a high percentage of readily digestable animal proteins. Among the countries bordering the Indian ocean, India is the largest and it countributes to about 45 percent of the fish production from the region. The fisheries of the countrty is in the transitional phase from the traditional to the modern ways of exploitation.

On the exploitation of common property, fishery resources are threatened by 'over fishing'. Regulation of a type leading to a reduction in the number of fishing units seems desirable to conserve valuable resources, fore-stall economic difficulties and reduce the likelihood of political clashes. In Tamil Nadu, recently, there has been clashes between catamaran operators and mechanised boat operators, due to the mechanised boats operating in areas which are traditionally fished by Catamaran. Besides creating a law and order problem the increased number of mechanised boats of 30 and 32 feet would further aggravate the situation. It is therefore necessary to plan the commissioning of boats for the future in a manner which would render the boats with longer operational range, so that the conflict between mechanised boat operators and catamaran operators would be minimised or avoided.

The use of new techniques to modify the resources of the seas holds out some promise for increasing the fish crop in India. India has a coast line of 6,500 kms. offering considerable scope for the establishment of fisheries and is ranked at present seventh among fishing nations of the world as far as fish production is concerned. The Bay of Bengal and Arabian Sea abounding in fishing grounds, gulfs and bays all along the coast and a large number of islands with their mangrove swamps and coral reefs are rich sources of marine fish.

Fishing in Indian seas is generally confined to a narrow coastal belt, 11-16 km. width and the richer offshore and deep-sea water are practically unexploited. This is largely due to the inadequacy of fishing craft and gear in use. Except for the mechanised craft recently introduced in some parts of India, fishing craft and gear in use throughout the country are indigenous, non-mechanised and locally built. They have been designed to suit local conditions. On the east coast, the sea is rough and the coast is surf beaten and the landing places are very few except the open coast. Consequently the chief craft used are the floating raft or the catamaran and non-rigid masula boat. On the west coast the sea is calm except during south-west monsoon when operations are almost suspended, and small canoes and large rigid and strongly constructed boats are operated.

A large variety of specialised nets have been developed for capturing different types of fishes and most of the fishing units are of a high operational efficiency in the inshore waters. The development of the Indian fishing fleet has proceeded along two lines viz: the gradual mechanisation and modification of indigenous boats and the introduction of new mechanised boats suitable for new fishing methods. The mechanisation of available indigenous boats is only a transitional phase and the real improvement of the Indian fishing fleet lies in the field of new designs.

Emphasis in the marine fisheries sector was on the mechanisation of indigenous crafts, introduction of mechanised fishing boats, improvements of fishing gears, establishment of infrastructure facilities such as processing plants, cold storages and landing and berthing facilities of boats, processing, transportation and marketing. These programmes backed by the discovery of rich fishing grounds in the inshore waters paved the way for the establishment of a seafood export industry for the welfare of fisherman and to the country. Research on various aspects of marine fisheries and exploration of their resources gave further impetus to the development of the Indian fisheries, which stressed on an increased production of fish to meet the protein requiremant in the Indian diet and improvement of socio-economic conditions of fishermen; and realisation of enhanced foreign exchange earnings through the export of selected marine products. Extension of fishing to under and unexploited areas, diversification of fishing and fish products, and improvement of traditional fisheries are the other core programmes of developmental strategy taken up during the period. Development of technologies in the culture of selected varities of fishes, prawns, shell fishes and sea weeds of commercial importance formed an important activity of marine fishery research. These technologies should be made available to the rural fishermen and the government may offer them some piece of land in the coastal backwater areas with some financial help to start coastal aquaculture in non-seasonal months.

Although fantastic advances have been made in fishing technology, practically it has not reached the poor fisherman. For example, the ecosounders used in detection of fish shoals are only in experimental stage to fishermen. Today thousands of mechanised boats are in fishing operation. But they do not have arrangements to make fruitful use of their effort. The old customery way of detection by casting the net is the only resort that they adopt. By luck, if the grounds are located, other boats crowd over that area to filter the water. This is due to many reasons (1) fishermen do not realise the importance of the device (2) the cost of the instrument and lack of expert hands for its operation (3) the fact that the expenditure they have to incur in detection of shoal is not minimized even by the use of the device (expenditure for running the boats). The problem is definitely more crude as it reaches the fisherman with Catamarans and canoes. Another problem is the difficulty in passing on the information regarding the existence of the fishery resources to the fisherman. Although to some extend, fishing forecasts are made possible, it does not have practical outcomes. If the fishermen are to have the forecast as is done for weather, it could have worked out advantageously. From a survey of Karala coast during recent years, it could be observed that fishing season in the different locations of the coast has been much scattered. Also during recent years, it was evidenced that fishing boats had good catches during the monsoon periods. From these, it could only be said that the fishing season is ill-defined or rather scattered. This has become an additional problem facing the fishermen as they have to keep a watch during the whole year for their catches. However, here also practical difficulties like risks involved in launching into the rough sea cannot be ignored.

The extension wings of all the marine fisheries research institutes by way of demonstration of diversified fishing methods and publication of the results of the marine fishery resources survey could bring the knowledge to the fishermen thereby to benefit the country. Although the existing extension services help to disseminate the technology developed in the country to the fishermen, fish farmers and the industry to certain extent, a well planned system of extension both in the state and national level is to be organised and strengthened to co-ordinate research, developmental and industrial activities so as to make the best use of the resources.

Most developed countries have attempted to maintain the living standards of fishermen and the ability of their fishing industries to compete effectively by providing price supports, subsidies' tariff protection and sundry fiscal advantages. Assistance in developmental efforts has usually been based on programmes for market expansion increased prdo.ctivity, exploration of fishing grounds and research on new gear and fishing methods.

With a view to promoting integrated fisheries activities, fisheries corporations were established in the country and subsequently all the maritime states also organised fisheries corporations. The working of the corporations include commercial fishing activities such as fishing operations, ice production, processing, storage, marketing and construction and repair of fishing vessels. To provide assistance to fishermen who are the actual producers, fisheries co-operative system in the country was organised. These socieites are engaged in a variety of activities such as fishing operations, marketing and providing facilities like short term loans for the purchase of fishing implements. Besides the subsidies provided by the central and state governments on various items of fishing requisites, credit facilities for the promotion of the industry are provided by the commercial banking institutions.

Several factors such as low social status, poor economic conditions, illiteracy, heavy leaning on middle men, traditional fishing equipments and methods of fishing low production rate and income influence the socio-economic onditions of fishermen. Though the answer to the problems of the fishermen may be the fishery co-operatives, much has yet to be done in the matter of actual management. ●